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THE RARE ALKALIS IN NEW ENGLAND

BY

FRANK L. HESS, ROSCOE J. WHITNEY, JOSEPH TREFETHEN, AND MORRIS SLAVIN

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

THE RARE ALKALIS IN NEW ENGLAND[1]

By Frank L. Hess,[2] Roscoe J. Whitney,[3] Joseph Trefethen,[4] and Morris Slavin[5]

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FOREWORD

"New England" and "granite" if not synonomous are at least associated terms. Where there are granites that are not deeply eroded there are usually pegmatites, the most erratic of rocks, and of them New England has a full portion.

Many of the New England pegmatites contain the rare alkalis - lithium, rubidium, and cesium. However, the same inhomogeneity of the earth's crust that has made the New England pegmatites unusual, in that so many of them contain the rare alkalis, has likewise made the distribution of the rare-alkali minerals sporadic even in those pegmatites, and most contain only enough to furnish collectors with more or less ornamental and uncommon minerals. New England has long had numberless collectors of minerals, and the mineralogists of its various schools have published many papers on the pegmatitic minerals, including those of the rare alkalis, but none of the papers have dealt with estimates of quantities. In this paper we have tried to place the emphasis on quantity rather than on mineralogy.

Lithium is by far the most plentiful of the rare alkalis, and the most plentiful lithium mineral in New England is spodumene; second in total quantity is lepidolite, followed by triphylite, which is not known in any considerable quantity elsewhere in this country. Other lithium-bearing minerals - amblygonite, petalite, lithiophilite, colored tourmalines (pink, blue, green, and nearly colorless). some beryls, cookeite, and cryophyllite - are found in smaller quantity. Although the oxides of all of the other alkali

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metals may form as much as 2 or 3 percent of microcline, only two specimens have been found that show as much as 0.5 percent Li_2O, and only a few as much as 0.2 percent Li_2O.

Rubidium is well-known as a constituent of lepidolite, and it is also known in biotites.[6] Small percentages have been found in rhodozite, itself a rare mineral, and several authors, in particular Vernadsky[7] and Quensel,[8] have shown that a microcline may carry as large a percentage as the lepidolites. Numerous microclines found in New England have been shown to carry rubidium, and a few rival the high-rubidium minerals found elsewhere. Although rubidium is undoubtedly more plentiful than cesium, there is no known rubidium mineral, that is, a mineral of which rubidium is an essential constituent.

Cesium forms the rich silicate, pollucite. As much as 2.5 percent Cs_2O is found in one New England lepidolite, 2 percent in several microclines, and a smaller percentage in some beryls. So far Maine has been the largest producer of cesium, its nearest rival being a single pegmatite - that in Tin Mountain, 7 miles west of Custer, S. Dak. Outside of New England and South Dakota, pollucite has been reported in the United States only in small particles at Pala and Mesa Grande, San Diego County, Calif.[9] The only known foreign deposits are in the pegmatite at Varutträsk, Sweden,[10] and the long-known small pegmatite at San Piero, Isle of Elba.

DISTRIBUTION OF THE RARE ALKALIS

The lithium minerals - spodumene, lepidolite, triphylite, colored tourmaline, lithiophyllite and petalite - have been found in Maine, Massachusetts, Connecticut, and New Hampshire, and quantitatively probably in the order named.

Rubidium is found in the lepidolites, in phlogopite from Vermont, and has been found in a least fractional percentages in every microcline of forty-four tested from the first four New England States named; in twenty-two of the forty-four a content of 1 to 3 percent of rubidia (Rb_2O) was indicated.

6/ Hess, Frank L., The spodumene Pegmatites of North Carolina: Econ. Geol., vol. 35, 1940, pp. 942-966.

7/ Vernadsky, W., Sur le microcline a rubidium: Soc. Franc. Min. Bull., vol. 36, 1913, pp. 258-265.

8/ Quensel, Percy, Minerals of the Varutrask Pegmatite. VIII. The Amblygonite Group: Geol. för. i Stock. Förh., vol. 59, 1937, pp. 467-468.

9/ Schaller, W. T. (quoted by Fleischer, Michael, and Ksanda, C. J.), Dehydration of Pollucite: Am. Mineral., vol 25, 1940, p. 666.

10/ Quensel, Percy, Minerals of the Varutrask Pegmatite. XIII. Pollucite, Its Vein Material and Alteration Products: Geol. for. i Stock. Forh., vol. 60, 1938, pp. 612-634.

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Cesium, contained in the mineral pollucite, has been found in Maine and in very much smaller quantity in Massachusetts. Lepidolite, the lithium mica, which nearly always contains some cesium and more rubidium, has been found, as stated, in all four of the lithium-bearing States.

LITHIUM

Lithium was discovered by Arfvedson[11] (also spelled Arfwedson in German publications) in 1817 in petalite (from Uto, Sweden), in which he determined the Li_2O as 5.76 percent. He also determined lithia in spodumene as 8.85 percent and in lepidolite as 4.30 percent, but the discoveries were not announced until the next year. At the same time, Berzelius[12] showed that rubellite (pink or red tourmaline) contained lithium, but that shorl (black tourmaline) did not, and he thought that the occurrence of lithium in tourmaline was adventitious.

The discovery of a lithium mineral in the United States was apparently first noted in a letter of Thomas Nuttall's[13] dated November 22, 1823, in which he announced the discovery of spodumene in the town of Sterling, Mass., and said that it had also been found "in a collection of specimens from the vicinity of Deerfield, Massachusetts."

Samuel Robinson[14] noted, in 1825, the occurrence "1 mile east of the courthouse in Paris, Me.," of "lepidulite (sic) of great beauty;" and in another line, "in great abundance at this place, sometimes crystallized in six-sided tables, and forming short columns." He also noted the occurrence at the same place of indicolite, rubellite, and green and white tourmaline. He does not mention that they contained lithium, and it was probably not known in the colored tourmalines other than rubellite.

In the first edition of his System of Mineralogy, printed in 1837, page 536, J. D. Dana reports the known occurrences of lepidolite thus:

11/ Arfvedson August, Undersökning af några vid Utö Jernmalms-brott traffade Fossilier och ett eget deri funnet eldfast Alkali: K. Vet. Acad. Hand. for år 1818, Stockholm, 1818, pp. 23-28.
Arfwedson A. Untersuchungeneiniger bei der Eisen-grube von Uto vorkommenden Fossilien und von einem darin gefundenen neuen feuerfesten Alkali: Schweigger's Jour., vol. 22, 1818, pp. 93-117.

12/ Berzelius, J. J., Zusatz to Arfwedson's article: pp. 117-120.

13/ Journal, Philadelphia Academy of Natural Science, vol 3, pt. 2, 1824, pp. 284-286.

14/ Robinson, Samuel, Catalogue of American Minerals: 1825, p. 5.

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Goshen and Chesterfield, Mass., afford rose-colored crystals of mica in granite, associated with turmaline (sic). An emerald-green variety occurs at Brunswick, Me., and the lepidolite variety at Paris of the same state, where it is intersected by crystals of red turmaline. The same variety is also found at Middletown, Conn.

CESIUM AND RUBIDIUM

Neither cesium nor rubidium was known when Robinson's and Dana's books were written. The two elements were first determined in New England minerals by Blake and Allen,[15] who found them in lepidolite from Hebron. In 1886 R. B. Briggs[16] determined them roughly in lepidolites from Paris, Hebron, and Norway, Maine. In 1891 Loren B. Merrill[17] found pollucite in a pegmatite at Hebron, Maine - the first new find in the 45 years that had elapsed since 1846, when Breithaupt[18] discovered the mineral with petalite on the Isle of Elba, did not recognize the petalite, and called the minerals "pollux" and "kastor" because they were as difficult to tell apart as the mythical twins.

Since Merrill's discovery, the mineral pollucite has been found at a number of other places, went through an intense but short-lived boom, and,

15/ Allen, O. D., Observations on Caesium and Rubidium: Am. Jour. Sci., ser. 2, vol. 34, 1862, pp. 367-373.

16/ Clarke, F. W., Researches on the Lithia Micas: Am. Jour. Sci., ser. 3, vol. 32, 1886, p. 356. Also in Report of Work Done in the Division of Chemistry and Physics Mainly During the Fiscal Year 1885-86: U. S. Geol. Survey Bull. 42, 1887, p. 19.

17/ Wells, H. L., On the Composition of Pollucite and Its Occurrence at Hebron, Maine: Am. Jour. Sci., ser. 3, vol. 41, 1891, pp. 213-220.

18/ Breithaupt, August, Neue Mineralien; Kastor und Pollux: Pogg. Ann., vol. 69, 1846, pp. 436-439.
Breithaupt did not recognize petalite, although it had been described in 1800 by d'Andrada (Scherer's Jour., vol. 4, 1800, p. 36). C. F. Plattner (Chemische Untersuchung. Zweier neuen vom Herrn. Prof. Breithaupt mineralogisch bestimmten Mineralien von der Insel Elba: Pogg. Ann., vol. 29, 1846, pp. 443-447) determined the cesium as potash because cesium was not yet known. Plattner's determination left a shortage of more than 7 percent in his analysis, and the fact that he published the analysis with this shortage is a monument to his scientific honesty and courage. Cesium was not discovered until 1861.
For the discovery of cesium and rubidium, see Kirchoff, G., and Bunsen, R., Chemische Analyse durch Spectralbeobachtungen: Pogg. Ann. Phys. u.Chemie, pt. II, vol. 113, 1861, pp. 337-381. A translation was published as "Chemical Analysis by Spectrum Observations." 2d Mem., L. E. and D. Phil. Mag., ser. 4, vol. 22, 1861, pp. 329-349.

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at least for the present, has returned to a place among the mineralogical curiosities.

PEGMATITES

As all, except phlogopite, of the rare alkali-bearing minerals treated in this article are found only in pegmatites, what the authors understand that term to mean will be stated:19/

A pegmatite is a rock formed from the solutions expelled from a cooling molten mass of granitoid rock and in its simplest form is an irregular, coarse-grained rock having the same essential minerals as the granitoid rock to which it is related, but usually has very much larger and very unevenly distributed individual minerals. Most bodies of pegmatite are elongated and dikelike and may be more than 1,000 feet long and more than 400 feet wide, but far the larger number are much smaller and may be of any shape.

Pegmatites are formed when a mass of molten granite is intruded into cooler rocks and begins to freeze; because molten granite is not merely rock softened by heat, but is a mixture of molten rock and water; and when it freezes and crystallizes, the water, at a temperature that would make solids glow, and under tremendous pressure, is forced out as a solution containing large quantities of dissolved mineral matter. The solution is pushed into cracks in the surrounding or overlying rocks or, less commonly, into cracks in the already frozen outer part of the granite, where the material in solution also freezes and is freed from water. The quantity of contained water in the liquid masses squeezed out of the solidifying magma allows extraordinary movement of ions, so that the minerals formed from them crystallize coarsely and unevenly. This is the primary type of pegmatite, and it rarely contains useful aggregates of minerals. Occasionally, however, the mass may be almost pure feldspar. A few of the New England pegmatites may tentatively be placed in this class, including the Ruggles pegmatite at Grafton Center, N. H., and the Bennett pegmatite about 3 miles west of Buckfield, Maine, parts of both of which have been replaced by later solutions. The Perham pegmatite about a mile southwest of West Paris is possibly of the same type. It has some replacements along the sides.

Nature is prodigal and careless with her works, and both the mixed primary pegmatites and the feldspar masses may be replaced or metamorphosed to any degree by later solutions. The body of microcline in the

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19/ Hess, Frank L., The Natural History of the Pegmatites: Eng. and Min. Jr. Press, vol. 120, 1925, pp. 289-293.

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Ruggles quarry at Grafton Center, N. H., may be taken as an example. Replacement on a small scale by uraninite (now largely weathered to other minerals) is shown by a photograph of a specimen reproduced in figure 1. As will be seen by reference to the figure, cracks have cut across a crystal of microcline, the continuity of which is clear, and uraninite, dendritic in three dimensions, has replaced the microcline. Figure 2, a radiograph of the same specimen, brings out the dendritic structure somewhat more clearly. Figure 3 shows replacement by uraninite of a much more complicated pattern.

Replacement on a larger scale, in which the potash feldspar in perthitic microcline is replaced by quartz and muscovite, although the perthitic lines of plagioclase show little loss is indicated in figure 4. Similarly replaced feldspar was found in a pegmatite worked for mica by C. E. Smith, 2 miles N. 70° W. of Alexandria, New Hampshire. Chudoba and Kleber[20/] have described an occurrence in Brazil in which the plagioclase lamellae were attacked preferentially.

Larger replacements cannot be shown by photographs but may be seen readily in the quarry. Most conspicuous are very coarse "corduroy" or graphic granite masses in the southeast wall which can be seen to spread from large gray-quartz veins. Also connected with the quartz veins are masses of "bull-head" 3 feet in diameter. "Bull-head" is a local name for aggregates of muscovite flakes 1/8 inch to 1 inch across and perhaps one-fourth as thick mixed with smaller feldspar crystals. Connected with the same veins are irregular, flat bodies of greenish feldspar, quartz, and muscovite 2 to 3 feet thick and 15 feet long. There is much other replacement that is perhaps less striking and less apparent but more extensive.

After the granite freezes, it acts like any ordinary cooling solid and shrinks as its temperature lowers. The covering rocks, including that part of the granite that has already cooled, settle and crack, and the cracks tend to follow old lines of weakness, including the markedly weak lines along which the pegmatites have been formed, so that the pegmatites also are cracked, and solutions from the still cooling granite follow the newly opened channels. The first thick solutions represented by the crystallized pegmatite have cooled, of course, and the new hot solutions bring in new materials and also have a dissolving power that may allow them to dissolve and redistribute the already crystallized feldspars, mica, and quartz, so that great masses of feldspar and quartz may be segregated and large crystals of mica may be formed either in the cooler outer shell of the pegmatite or, if the pegmatite body is large and has become sufficiently cooled, along cracks through the

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20/ Chudoba, Karl, and Kleber, Willi. Uber Feldspar von der Serra do Espinhaco, Brazil. Zentr. Mineral. Geol., 1940, A. pp. 161-166.

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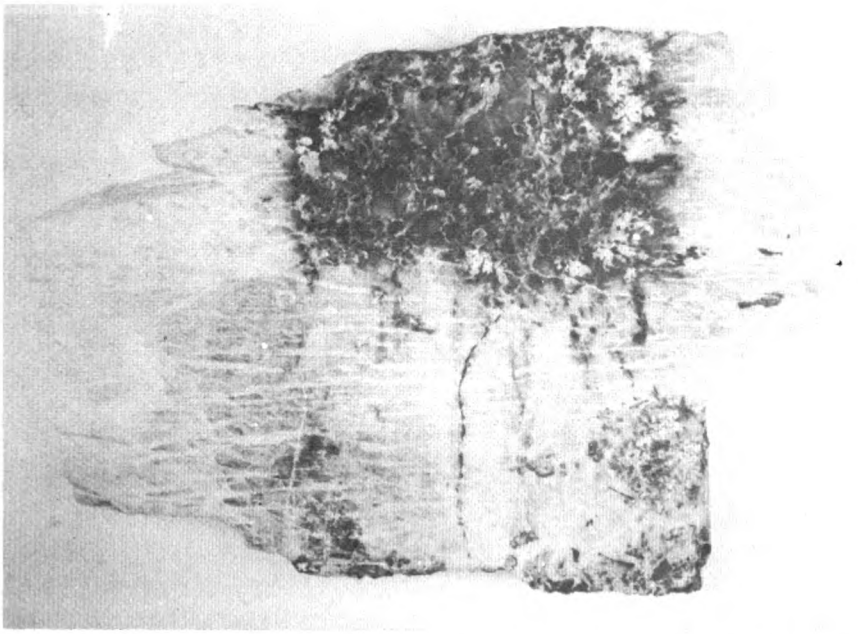

Figure 1.- Photograph of perthitic microcline partly replaced by uraninite. Cracks along which replacement minerals were introduced are visible. Ruggles mine, Grafton Center, N. H. Polished specimen loaned by Ward's Natural Science Establishment, Inc., Rochester, N. Y. Photograph by Howard Carl. x 1.

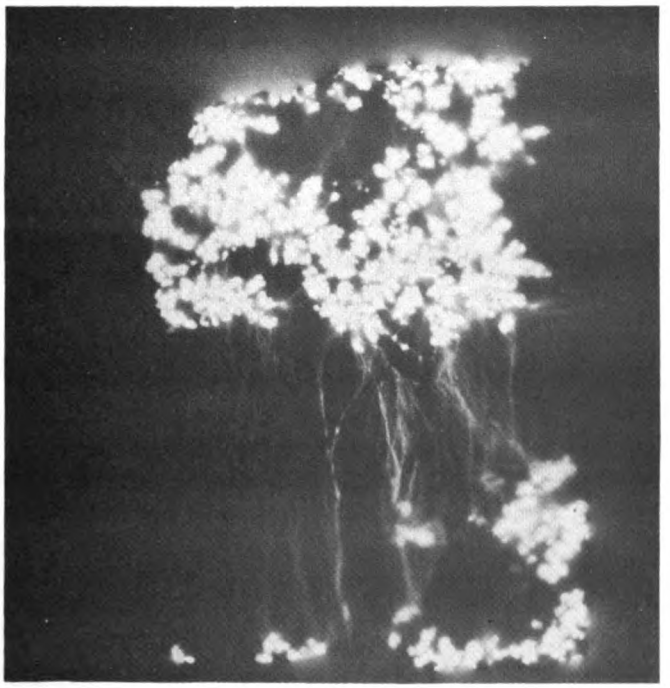

Figure 2.- Radiograph made by placing specimen shown in figure 1 on a sensitive film for 24 hours.

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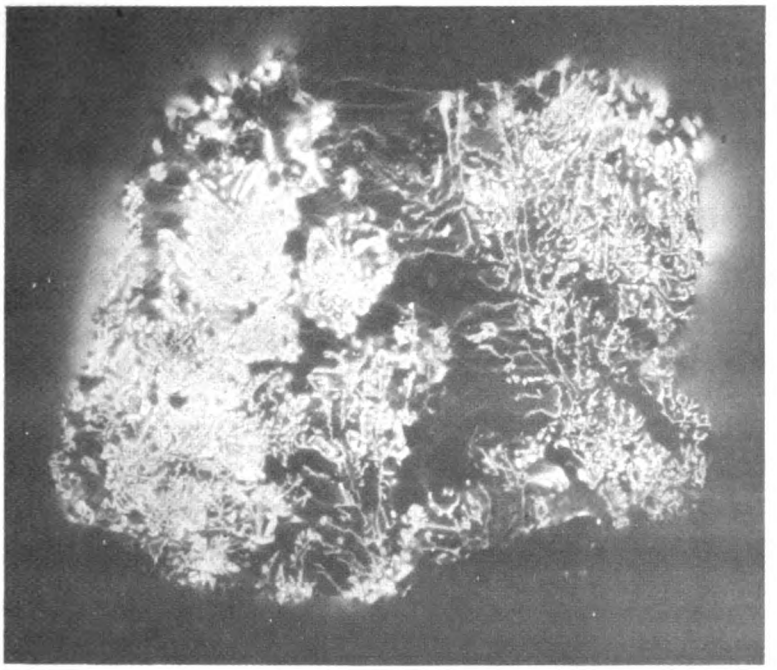

Figure 3.- Radiograph made by a polished specimen of microcline partly replaced by uraninite in a much finer pattern than shown in figures 1 and 2. Contact exposure, 24 hours. Specimen loaned by Ward's Natural Science Establishment, Inc., Rochester, N. Y. x 1.

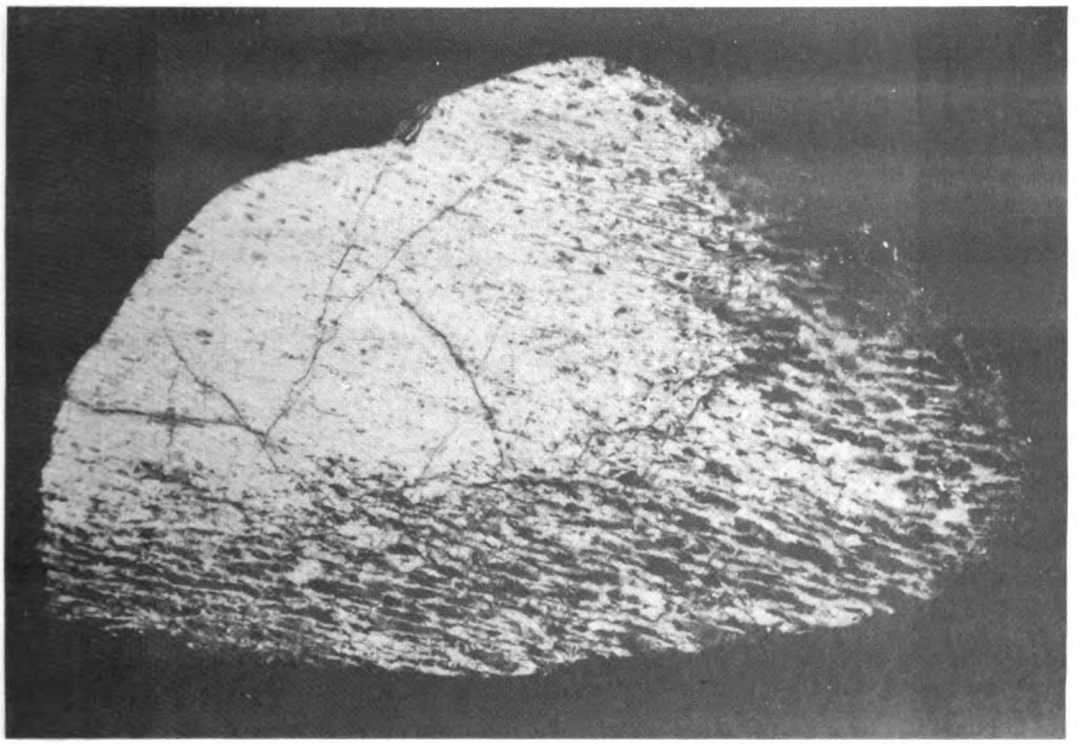

Figure 4.- Perthitic microcline in which the microcline is replaced by quartz and mica. The perthitic lines of plagioclase are not replaced. Ruggles mine, Grafton Center, N. H. Photograph by Howard Carl. x 1.

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mass. If the pegmatite is not more than about 10 feet thick, large books of mica may be distributed all through the mass.

Occasionally, solution along cracks in the pegmatite may take place more rapidly than deposition, so that microlitic cavities or vugs, such as those found in Paris Hill, at Topsham, and other places, will be formed. In the vugs later solutions may deposit comparatively few crystals (such as the tourmalines of Paris Hill), which the open space saves from breakage by succeeding movements; or the vug may be filled, and the filling, including the crystals, will then be cracked like other parts of the pegmatite.

The new solutions flowing through the cracks of the pegmatite tend to raise its temperature toward the degree at which it left the freezing granite, and minerals of higher precipitation points, such as those of the lithium group, replace the ordinary granitic minerals.

At times during the adjustments accompanying cooling and shrinking of the granite, but after the first flow of pegmatitic solutions, cracks may break through already frozen granite dikes, and solutions following the cracking may replace the granite just as in other places they replace the first-stage pegmatites. An excellent example is the pollucite-bearing pegmatite on Hodgeon Hill 3 miles southwest of Buckfield, which was the first to be worked for cesium.

The hot solutions come from every possible part of the freezing magma (the mass of molten rock) and are collecting agents for all of the unusual elements that are held in the magma as mere traces, as well as for the more common elements. The less common elements include the rare alkali metals (lithium, rubidium, and cesium) and beryllium, all of which are found in the pegmatites and virtually only in the pegmatites or in closely related rocks. These elements seem to form compounds soluble at the temperatures of the molten magma but precipitated by a slight lowering of the temperature. Once precipitation has started a nucleus of some mineral, ions of the same type are attracted from the passing flow of dilute fluid, and masses are built up, the size of which depends on time, tenor, constancy of temperature, volume of the flow, and probably also on the extent of cracking of the first-stage pegmatite or the granite through which the solutions are flowing.

Periods of cracking due to adjustments of the earth accompanying the shrinkage of the cooling magma succeed each other at irregular intervals. Pegmatites may be cracked repeatedly nearly parallel to the walls and so be more or less roughly sheeted, that is, so cracked as to be divided into rough sheets. Other cracks may form at any angle to the walls. Channels (cracks) along which solutions have been flowing may become clogged, and new

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courses may be opened. These events, coupled with the fact that new minerals can be deposited no faster than the older minerals are taken into solution and removed, furnish reasons for the well-known erratic occurrence of the minerals in pegmatites.

Not only are the channels along which flow the replacing solutions changed from time to time, but the temperature of the channel walls, chilled at first by contacts with the country rock, is raised as the flow of fluids from the freezing magma continues. This rising temperature, of course, means a difference in the minerals taken into solution and in the minerals deposited, so that a succession of minerals may be formed, dissolved, and replaced.

First, as already noted, there is a redistribution and possibly a new deposition of quartz and of potash feldspar, all of which is perthitic, that is, having thin, irregular lines of albite or some other plagioclase distributed through it. These minerals, in turn, then may be replaced by a great variety of other minerals as the flow of solutions continues. What the new minerals may be is wholly unpredictable because the magmas are diverse, and the damming of old channels or the opening of new ones cannot be forseen. Most cracks are closed entirely by the deposition of minerals from solutions flowing through them, but some are never healed. Such unhealed cracks are prominent in the upper Smith pegmatite, near Alexandria, N. H. Others that cut spodumene in a pegmatite at Lithia, Mass., are shown in a reproduced photograph of a polished slab (figure 12). Although heretofore unnoticed, such old open cracks are probably common.

The time comes, of course, when the solutions from the granite magma cool, and then minerals such as scheelite, molybdenite, fluorspar, zincblende, and galena, deposited at lower temperatures, may be introduced into the pegmatites.

Of great importance is the fact that the changes of channels and of replacements make the continuation of mineral bodies in pegmatites so uncertain as to allow only the most general conclusions about them.

RARE-ALKALI DEPOSITS

Maine

Distribution. - The pegmatites known to carry rare alkali minerals are in the southwestern quarter of the State in an irregular belt running from Auburn northwest to Andover, about 50 miles long and 15 miles wide, with an outlier at Warren, 50 miles east of Auburn.

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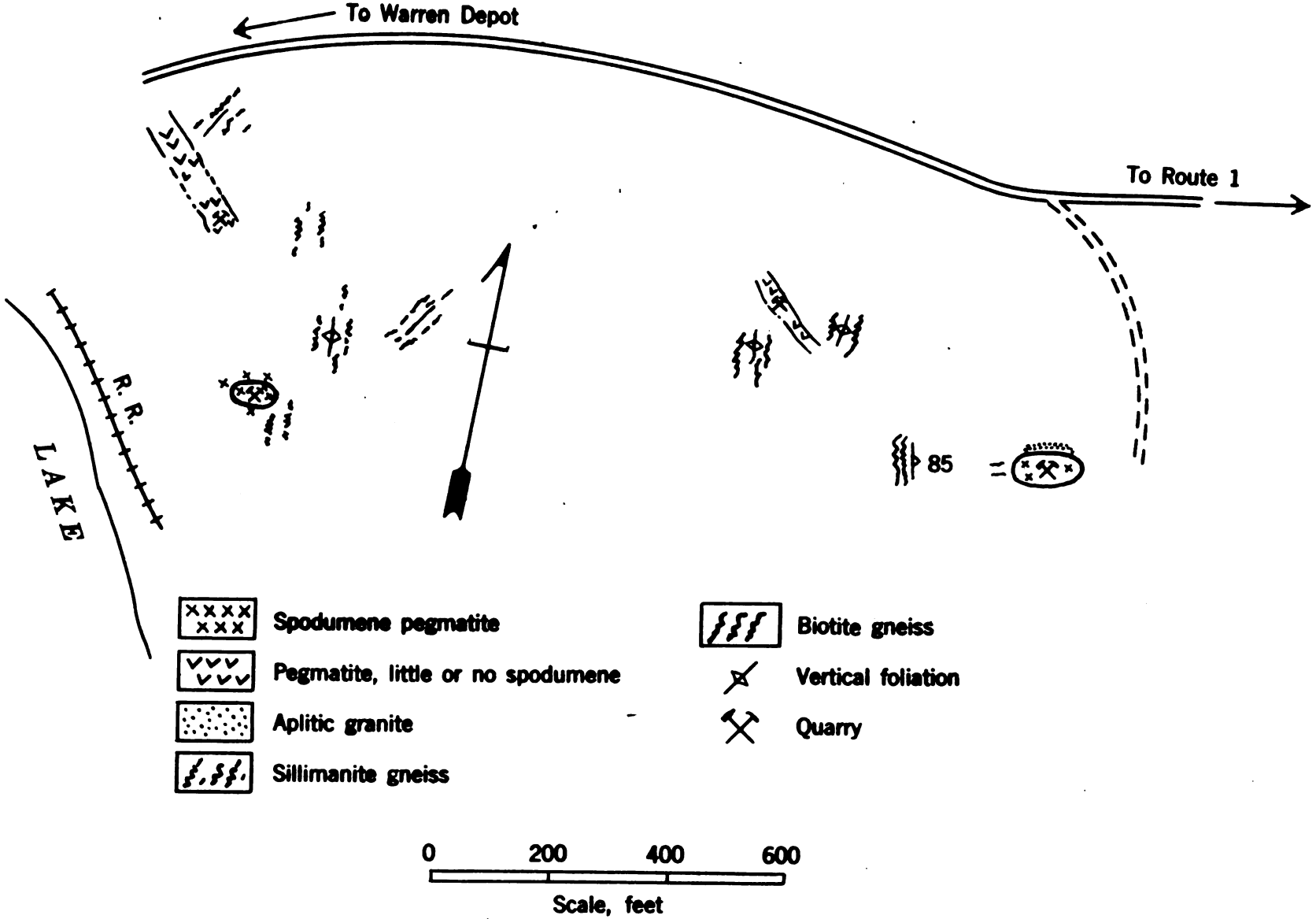

Figure 5.—H. G. Starett spodumene prospect, Warren, Maine, May 17, 1941.

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Warren. - About 2 miles west of the village of Warren and about 100 yards south of the road (see fig. 5) is an almost round pegmatite 50 feet in diameter on flat wooded land owned by H. G. Starrett. The pegmatite is at the edge of a rather fine-grained biotite granite, with which it is probably genetically connected, yet no biotite has been seen in the pegmatite, in which the only dark minerals are black tourmaline in small crystals near the sides and a few very small scattered crystals of columbite and cassiterite. Small tourmaline suns occur in the biotite granite on the northside of the pegmatite. Some small grains of uranium minerals and some white beryl are said to have been found. Small lumps of lithiophilite, partly changed to purpurite, and flakes of white lepidolite occur here and there.

The body of the pegmatite is a fairly coarse mixture of microcline, quartz, and some muscovite, with individual feldspars 4 or 5 inches across. Part of the microcline is fetid when freshly broken and is what has been called necronite. Some of the quartz is also fetid but is less smelly than the feldspar. The cause of the odor is unknown but possibly is due to a phosphorous compound.

Spodumene is not evenly distributed through the pegmatite. Our collective estimate was that about 25 percent or possibly a little more of the exposed pegmatite contains about 10 percent of spodumene. None could be seen in the remaining 75 percent. The spodumene evidently has been deposited from solutions following cracks, and the crystals may be wholly in the plane of the cracks, so that a slab an inch thick contains them, though in other places the crystals lie at various angles to the plane.

The crystals average possibly 1-1/2 inches in width, 3/4 inch in thickness, and 3 inches in length. These dimensions must be taken as generalizations, and are not given from actual measurements - many crystals are much larger and are said to reach a width of 6 to 8 inches. In general, the crystals are fresh and unweathered, but a few have a horny appearance and have been replaced by pinite, a translucent mass of microscopic particles of muscovite. Some are surrounded in whole or in part by radial or wavy masses of muscovite with its edges perpendicular to the spodumene. This is the material that has been called, successively, pihlite,[21] cymatolite,[22] and aglaite[23] in the belief that it was a new mineral.

21/ Sefstrom, N. G. His work on pihlite is described and his analysis quoted by Svanberg, L. F., Kemisk undersökning af några glimmerarter samt några till glimmerfamiljen horande fossilier: K. Vet. Akad. Hand. för år 1839, Stockholm, 1841, Pihlit ifrån Brättsra backe vid Sala, pp. 131-182.

22/ Shepard, C. U. Quoted by Dana, J. D., and Brush, George J. System of Mineralogy; 5th ed., 1884, pp. 455-456. At first spelled cumatolite.

23/ Julien, Alexis A., Aglaite, a New Mineral Species: Eng. and Min. Jour., vol. 23, 1877, p. 217.

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Cymatolite is still used to designate the mass. Spodumene is replaced by it but, on the other hand, the cymatolite follows cracks through quartz and feldspar, where it has evidently replaced those two minerals only. Some crystals replaced by pinite have kept their crystal form and are surrounded by cymatolite. The pinite replacement has been called killinite,[24] also under the impression that it was a new mineral.

It seems probable that the spodumene may extend downward at least as far as it does horizontally, and there is, of course, a recognized possibility of greater or less depth.

If the estimate that a little more than 25 percent of the outcropping pegmatite contains about 10 percent of spodumene be taken, that the pegmatite be considered as round, and that it may be spodumene-bearing downward to a depth as great as the spodumene-bearing width, say 25 feet, the mass will have a volume of 12,000 cubic feet, or roughly 1,000 tons of rock containing 100 tons of pure spodumene. If the spodumene carries the ordinary average of 6 percent Li_2O, it will contain 2.8 tons of metallic lithium. This estimate is probably to be considered as less than the likely quantity.

In 1930, 30 short tons of hand-picked spodumene containing 5 percent Li_2O was sold from the property, and in 1933 about 18.5 tons was shipped. One mass of spodumene and quartz was 23 feet long and 5 feet wide, and tapered from 18 inches to 1 inch in thickness. (From a letter of H. G. Starrett dated April 10, 1941.)

About 1,500 feet west is another outcrop of pegmatite in which a small opening has been made, exposing a mixture of quartz, albite, and slender parallel crystals of spodumene as much as 4 inches long 1/2 inch wide, and 1/16 inch thick, having a worm-eaten appearance. The irregularity seems to be due to replacement of the spodumene crystals by quartz. Purpurite and triphylite are said to have been found with the spodumene.

Between the two outcrops of pegmatite most of the surface is soil-covered, but in places a sillimanite schist outcrops.

Plumbago Mountain, Newry. - One of the largest deposits of lithium minerals in Maine is found on Plumbago Mountain in the town[25]

24/ Thompson, T., Mineralogy, Geology, and Mineral Analysis: Vol. 1, 1836, pp. 330-332.

25/ In New England, the word "town" is used for a governmental division corresponding to the "township" of other parts of the United States, and "village" is used to designate a more or less compact settlement smaller than a city.

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of Newry, 7 miles by road south of Andover and 12 miles by road (9 miles in a direct line) west of Rumford, Maine. The top of Hall's Ridge a northeast spur is somewhat less than a mile west of the west Rumford-Andover road (Highway No. 5), 860 feet above it, and has a narrow, comparatively flat, north-south extension several hundred feet long. This ridge affords the best example known to the authors of the different types of pegmatites that may be developed from one magma in a small area through changing channels carrying pegmatitic solutions that probably differed in temperature and that may have changed their content by dropping out and picking up various elements as they passed through the rocks (conceivably including other pegmatites) along their path.

Five pegmatites have been exploited in various degrees. The earliest work was done in 1901 to 1904 by H. C. Dunton for gem tourmaline on what has been known since as the Dunton pegmatite at the south end of the ridge top. The pegmatite was about 200 feet long and, where widest, possibly 50 feet across, with a north-south (magnetic) strike. The country rock next to the pegmatite is a green schist in which flakes of mica 1/4 inch in diameter are developed near the pegmatite, especially along cracks. Black tourmaline with smooth faces and 3/16 inch in diameter is developed in the schist next to the pegmatite, but none in it, and no colored tourmalines are found outside of the pegmatite.

In 1926 work was begun on the Dunton pegmatite by the General Electric Co., represented by W. D. Nevel, in a search for pollucite, the hydrous cesium aluminum silicate, $H_2O.(Cs,Na)_2O.Al_2O_3.5SiO_2$,[26] which he had discovered in the pegmatite in 1902. A considerable quantity was obtained by picking over the dump from the Dunton operations because the pollucite resembles quartz so closely that often one mineral has been mistaken for the other even by those who have had a considerable experience with them.

The pegmatite was of the distinctly metamorphic type, and although it contained some microcline there were no large masses. It was roughly sheeted by cracks 2 to 4 feet apart that cut the pegmatite lengthwise more or less parallel to the walls. The cracks were the loci for irregular belts, 12 to 18 inches wide, of cleavelandite in radial plates as much as 6 inches in greatest dimension, which was evidently introduced along the longitudinal cracks. The mineral shows little breaking. Muscovite, usually in feathery forms, was found in places along the walls and in other places along cross

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26/ Dana's System of Mineralogy, 6th ed., 1892, p. 344. The formula is an approximation and others differ considerably. W. E. Richmond and F. A. Gonyer, On Pollucite: Am. Min., vol. 23, 1938, p. 787, find it to be $Cs_{14+x}Al_{14+x}Si_{34-x}O_{96}\cdot nH_2O$ in which x=0, 1, or 2. n=5-9.

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fractures. Radial manganocolumbite made fan-shaped crystals 1/16 to 3/32 inch in thickness and more than 5 inches across. The plates were unbroken or only slightly cracked and cut through cleavelandite, quartz, and blue tourmaline.

A few grains of uraninite reaching about 1/2 inch in diameter but mostly changed to gummite and uranophane, a few flat, pinkish-gray beryls 3 to 4 inches broad and an inch thick, beryllonite (one crystal of which weighed 2 pounds) (Personal communication from W. D. Nevel.), small crystals of herderite, sparse, small masses of black cassiterite reaching possibly 2-1/2 inches in thickness and, when crushed, making a purplish powder like that from other pegmatites in New England, the Carolinas and the Black Hills, and groups of little rose-quartz crystals lining small vugs also were found.

Lilac lepidolite occurred in small impure masses associated with the cleavelandite. Some were bounded by plates of cleavelandite, and all were cut by it. Not enough of the mica was found to have commercial value, although in 1906 Bastin[27] saw a mass 6 by 2 by 3 feet that contained some cleavelandite and tourmaline.

There were many tourmalines, all colored. Many had pink bodies and green skins and hence received the popular name of "watermelon tourmalines," some were pink at one end and green at the other, many were blue, and a few were blue-green with a pink skin. W. D. Nevel (in a personal communication dated May 12, 1928) described tourmaline, green at one end, pink in the middle, and blue at the other end, as much as 3 feet in length and 6 inches in diameter. Cleavelandite cut through some of the tourmalines. Little regularity of distribution could be seen, but undoubtedly highly heated solutions had deposited them through some of the rock on each side of the cracks.

As in other wholly metamorphic pegmatites, the black or deep-brown tourmalines were deposited by the solutions in the cooler places, and here they are in the country rock entirely outside of the pegmatite. So far as is shown by analyses, the higher-temperature colored tourmalines contain the rare alkalis and the lower-temperature black and brown tourmalines at most carry only traces, but usually carry none. That Berzelius[28] thought that the occurrence of lithium in tourmaline was adventitious is not

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27/ Bastin, Edson S., Geology of the Pegmatites and Associated Rocks of Maine: Geol. Survey Bull. 445, 1911, p. 77.

28/ Berzelius, J. J., Zusatz to article by A. Arfwedson: Schweigger's Jour. vol. 22, 1818, pp. 117-120.

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surprising, because when he wrote little was known about the origin of pegmatites and the distribution of tourmalines.

Sparsely distributed spodumene crystals were shaped like planks and were as much as 10 feet long, 17 inches wide, and 3 inches thick. (Letter of W. D. Nevel referred to above.) Some were pinkish. The quantity was insignificant.

A little amblygonite was found in flat crystals 1 to 2 inches thick and 3 to 4 inches broad with a clear-white porcelainous fracture, but one mass was estimated to weigh 800 pounds. (Letter of W. D. Nevel.) It was said to carry a trace of cesium. A little triphylite and lithiophilite (partly altered to purpurite) and a number of other phosphates in small rare, crystals also were found.

Pollucite was not seen in place by any of us. Specimens showed it lying against quartz and microcline smoothed by replacement. Part was clear and glassy, but part was more or less altered to clay and was so greatly broken that it looked like crushed, clouded feldspar. The clear mineral was said to carry 33 percent Cs_2O and the cloudy mineral 24 to 28 percent Cs_2O. One mass found on September 20, 1927, weighed about 1,000 pounds. It is thought that during the first season's work (1926) about 1,200 pounds of pollucite was obtained, most of it from the dump of the workings for tourmaline. In 1929 less than 50 pounds of pollucite was obtained, and operations were closed in September. How much pollucite was produced altogether from the pegmatite is unknown, but it is supposed to have amounted to 3,500 pounds or more. No pollucite has been found in any other pegmatite of the Plumbago Mountain group.

The broken condition of tourmaline and pollucite and the comparatively unbroken condition of manganocolumbite and albite seem to indicate that the first two were formed before the second couple of minerals.

About 200 feet along the top of the ridge north of the Dunton pegmatite is another but much smaller lens that in 1926 showed a number of boardlike spodumene crystals, some of which had fairly good crystal terminations. The pegmatite contains some pearly-gray lepidolite and a somewhat smaller quantity of lilac-colored lepidolite. Cleavelandite cuts through the lepidolite as in the Dunton pegmatite and as it does in most occurrences known to the writers. In 1940, as in the other pegmatites of the ridge, collectors, amateur and professional, had picked the bones bare, and little but quartz, cleavelandite, and muscovite was left, though the exposure was larger.

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About 100 feet farther north is another and somewhat larger lens on the west side but near the top of the ridge. As seen in 1926, it was about 100 feet long and 15 or 16 feet wide. It contained some pearly-grayish lepidolite that was reputed to have a very high rubidium content, but tests of several specimens did not confirm the report. There was also a little white lepidolite in plates 7 or 8 inches broad, some was lavender colored, spherical, and about 3 inches across, and some muscovite sheets several inches across had lilac-tinted patches of lepidolite. This pegmatite also contained board-shaped crystals of spodumene 6 to 8 inches across, a little more than 1 inch thick, and 5 to 6 feet long.

There were a few blue tourmalines about an inch in diameter. As in the other pegmatites, cleavelandite was common and at one place were three well-crystallized microcline crystals, one 12 by 18 by 26 inches with one about half as large on each side. In 1940 no unusual minerals were to be seen.

Possibly 500 feet in a direct line down hill southwest of the Dunton pegmatite another was opened with an exposed perpendicular face about 70 feet long and 12 feet high. The mass was aplitic and was roughly sheeted parallel to the enclosing mica schist. The sheeting was of two distinct ages. The first, composed of only a few cracks, had been healed and in part obliterated by solutions that replaced the aplite (which is to be considered as a fine-grained phase of the pegmatite) with coarser pegmatite. The later sheeting cuts through both aplite and pegmatite.

The coarser pegmatite was bordered by muscovite in irregular plates 2 or 3 inches across. As shown by the rough field sketch made in 1927 (fig. 6), the pegmatite occupied most of the lower part of the mass as exposed but it cut through the aplite to the top, bordered by the mica, except at the wall. A strip of the mica also followed one of the sheeting cracks part way across the aplite. The coarser part of the pegmatite was largely cleavelandite and quartz that had replaced most other minerals.

Spodumene was more plentiful here than in the other pegmatites of the ridge. One crystal, as exposed, was 10 feet in length and 13 by 8 inches in cross section. Many of the crystals had pyramidal terminations. So far as was observed, cleavelandite did not replace spodumene, columbite, uraninite, or cassiterite: but, on the other hand, it formed radiating masses using the spodumene as a base.

A little amblygonite was present in small, white, flat crystals two or three times the size of one's palm. They seemed to be replaced by green tourmaline, lepidolite, and albite.

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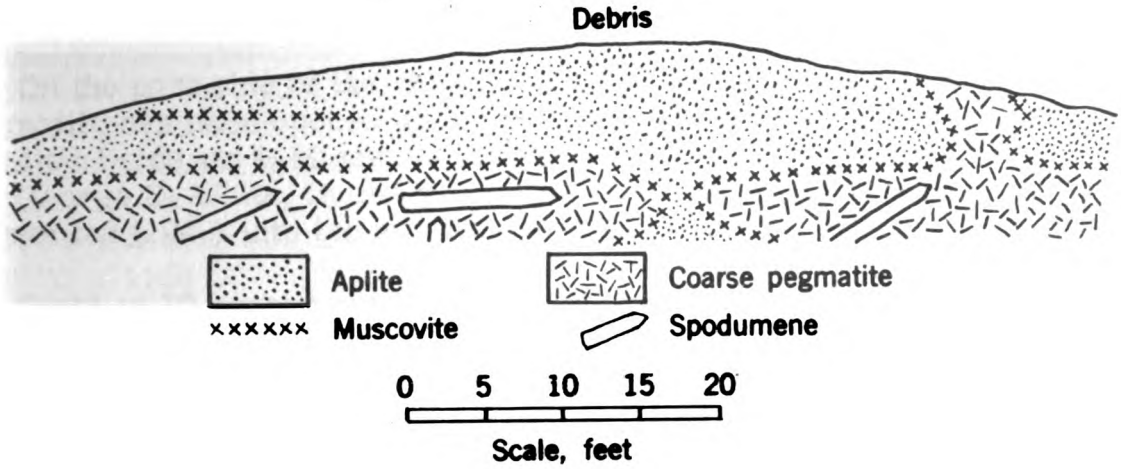

Figure 6.—Field sketch of pegmatite about 500 feet southwest of Dunton pegmatite, Hall's Ridge, Plumbago Mountain, Newry, Maine, September 30, 1927.

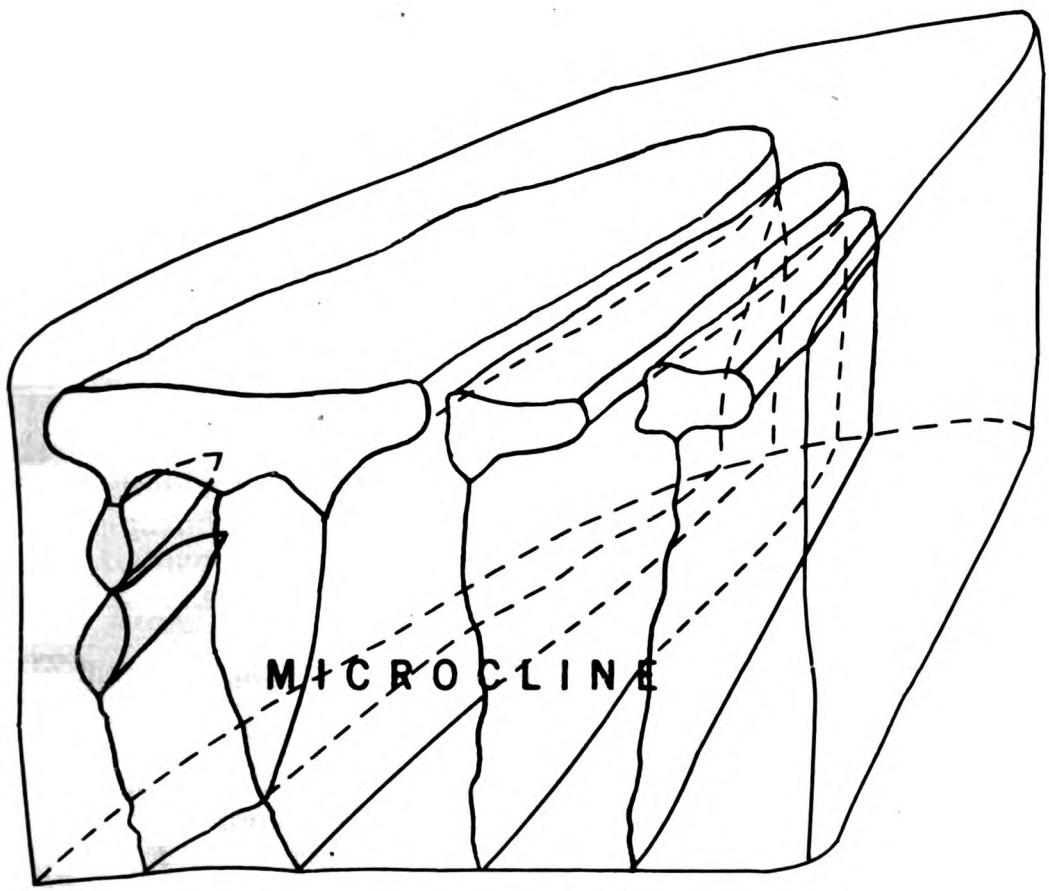

Figure 7.—Stereogram showing possible form of bodies of triphylite, quartz, and mica in pegmatite on east side of Hall's Ridge, Plumbago Mountain, Newry, Maine.

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On the east side of the ridge, about 300 feet below the Dunton quarry, a pegmatite has been opened up for potash feldspar and is being worked by the United Feldspar & Minerals Corporation. A mass of microcline estimated by George D. White, in charge, to be 30 feet wide and 75 feet long, had been worked (1940) into the hill to a face 25 to 30 feet high.

Eight or 10 cracks cut the pegmatite more or less vertically and parallel to the sides, similarly to those in other pegmatites on the hill. Along these cracks, to a depth of 6 or 8 feet below the surface, the feldspar had been replaced by a mixture of granitic minerals. Bordering this mixture on the bottom, and crossing the cracks from the top to 5 feet below, was an irregular layer as much as 2 feet thick and 25 feet long of muscovite in unoriented plates 1 to 3 inches wide. Along the cracks and spreading from them were masses made up of mica, quartz, and triphylite (iron-lithium phosphate containing some manganese). The brownish-yellow triphylite was stained bluish on the outside by vivianite (hydrous iron phosphate). The masses as shown in the face of the quarry in the fall of 1940 reached 4 or 5 feet in thickness and were partly fused together horizontally, (See fig. 7).

The cracks were more or less parallel to the walls; the masses evidently followed the cracks, and so were elongated with the pegmatite. Many tons were hauled out and dumped on the mountainside as waste. The bodies are now mined out.

Triphylite theoretically carries 9.5 percent Li_2O, as compared with 8.4 percent for spodumene and 10.1 for amblygonite. As a matter of fact, spodumene usually carries about 6 to 6.5 and amblygonite 8 percent Li_2O, soda usually replacing the remainder of the lithia.

This was the largest known deposit of triphylite and was probably one of the largest lithium deposits known in Maine. Although triphylite is found in small quantity in many of the pegmatites, the only other triphylite mass of notable size known in New England was at Center Strafford, N. H., where a nodular mass 10 feet across was found.[29]

As in the other pegmatites of this group, a little spodumene has been found.

Economically, the quantity of spodumene, amblygonite, and lithium minerals other than triphylite in the Dunton and associated pegmatites is negligible, except that during the present wave of interest in mineral

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29/ Switzer, George, Paragenesis of the Center Strafford, N. H., Pegmatite: Am. Min., vol. 23, 1938, p. 814-815.

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collecting the beautiful colored tourmalines, purpurite, and some attractive wavy spodumene that has been found (though in which pegmatite is unknown) attract numbers of amateur collectors with some resultant economic advantage to the region. Some crystallized rose quartz is still found.

As to whether more pollucite could be found by further quarrying, it can only be said to be among the possibilities.

Spectrochemical determinations of the alkali metals and some other elements in several minerals from the exploited pegmatites on Plumbago Mountain gave the following results:

	Na_2O	K_2O	Li_2O	Rb_2O	Cs_2O	Ga_2O
14. Microcline, Clean, from triphylite pegmatite	5.0	+5.0	0.2	1.0	0.1	n.d.
15. Microcline, sprinkled with albite, from triphylite pegmatite	5.0	+5.0	.2	1.0	.5	n.d.
16. Microcline, from Dunton pegmatite	5.0	+5.0	.1	3.0	1.0	n.d.
37. Lepidolite, gray, 200 yards east of the Dunton pegmatite	2.0	5.0	1.0	1.0	.2	0.5
38. Lepidolite, white, 500 feet northwest of the Dunton pegmatite	.5	2.0	5.0	2.0	2.0	.1
39. Muscovite from triphylite pegmatite	1.0	5.0	1.0	1.0	.2	.5
43. Triphylite	.3	.5	+5.0	.2	n.d.	n.d.

Note. - n.d. = too little to be determined.

All were tested for indium and germanium, but neither was detected. It is to be noted that spectrochemical estimates given in this paper are approximate only and may vary widely either way from the indicative figures given.

It will have been seen that a specimen of microcline from the Dunton pegmatite carried about 3 percent Rb_2O, so that more than 10 percent of the feldspar was rubidium microcline ($Rb_2O.Al_2O_3.6SiO_2$), a quantity about the same as that in the richest rubidium-bearing feldspars heretofore noted; for example, an amazonite (green microcline) from the Ilmen Mountains, Russia, was found by Vernadsky[30] to contain 3.12 percent Rb_2O, and a microcline from Varutrask, Sweden, is reported by Quensel[31] as containing 3.3 percent Rb_2O, 0.6 percent Cs_2O, and 0.34 percent Li_2O. The cesia

30/ Vernadsky, W., Sur le microcline a rubidium: Soc. Franc. Min. Bull., vol. 36, 1913, p. 226.

31/ Quensel, Percy, Minerals of the Varutrask Pegmatite. VIII. The Amblygonite Group: Geol. for. i Stockholm Forh., vol. 59, 1937, pp. 467-468

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(1.0 percent) content of the Dunton microcline is also large, but the lithia content (0.1 percent) is small.

Triphylite and its content of phosphorus and of the rare alkalis might be useful as a component of a fertilizer. Most, if not all, plant ashes that have been tested contain lithium, and it might be advantageous to have it and rubidium among the trace elements in fertilizers.32/

Hall's Ridge is separated from the main mass of Plumbago Mountain by a notch about 100 feet deep. Above the notch the mountain rises on the west almost precipitously 500 to 1,000 feet. The steep face has been formed by a pegmatite which the glaciers could not wear away as fast as they did the country rocks - here coarse biotite schists and greatly metamorphosed quartzose sediments that contained more or less feldspars and other minerals. Many of the mountain tops of the region have been held at their present height by pegmatites.

At a height of about 2,200 feet (between 1,500 feet and 1,600 feet above the highway) a sheet of pegmatite, 15 to possibly 25 feet thick and dipping about 15° northeasterly, cuts through a knob of the ridge. The edges of the pegmatite outcrop in an elongated oval, possibly 600 feet by 300 feet. At 27 points seen the upper 3 to 5 feet or more of the pegmatite has been considerably replaced by quartz. Spodumene is exposed at many places and, at several points where there is an apparent thickening of the quartzose phase, the spodumene occurs in crystals as much as 10 inches thick and nearly square. Some are in part glassy.

With the spodumene other lithium minerals in the outcrops are blue tourmaline; lithiophillite, weathered to purpurite; and what seems to have been triphylite, now weathered to spots of rusty material.

Beryl, largely white, but in part green, ranging from 1/4 inch to 8 inches in diameter and, as seen, about twice as long as thick, is found in all of the exposures. Most of the beryl seems to have grown about perpendicular to the over-lying schist. Many of the crystals have been broken and are partly replaced along cracks by cleavelandite. In other places cleavelandite forms masses that are made up of blades 3 to 4 inches across. White microcline is common and muscovite occurs in books 4 inches across and an inch or more thick. In two outcrops at the summit the mica is closely spaced for a distance of 6 or 8 feet. Part of the quartz is peculiarly limpid for the massive mineral. In some places the pegmatite gives off a fetid odor when broken.

32/ Since this paragraph was written the triphylite, as already stated, apparently has been almost wholly mined out.

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The best outcrop of spodumene seen was near the lowest part of the pegmatite on the northeast side and should the pegmatite be mined that would seem to be the best point to begin, driving toward the top and letting all rock move by gravity toward the opening.

Black Mountain, Rumford. - In a direct line, Black Mountain in the northeast part of the town of Rumford is 5 miles from Rumford village but it is 10-1/2 miles by road to the northwest foot of the mountain, whence it is 1-1/4 miles steeply up hill to the workings in the pegmatite. The workings are 5-1/2 miles northeast of the Plumbago Mountain pegmatite from which they are plainly visible. The mountain has been known many years for its colored tourmalines and was exploited for them by E. H. Bailey of Andover in 1889. It was later worked a while for scrap mica and more recently by Cesare Trusiani for feldspar. The workings are south 55° west from, and a short distance below, the top of the mountain. Work has been done in five considerable openings which, although relationships are not wholly clear, may be in a single pegmatite divided by inclusions of the schist country-rock or they may be in several separate bodies.

The pegmatite as shown in the several openings is exceedingly variable in composition. In the lowest opening, about 40 feet across, the pegmatite is mostly cleavelandite with a large quantity of black tourmaline but no rare alkali minerals. About 50 feet above are three openings in a row, though not on a level, in which the pegmatite contains a great deal of quartz with smaller quantities of numerous late pegmatite minerals and earlier muscovite.

The lowest and westernmost of the three openings is now largely filled with waste, but the vertical contact of the pegmatite and the biotite schist country-rock is well exposed. The contact curves over the pegmatite as if it had been a round-nosed mass shoved into place from below but the schist abuts against the pegmatite with no sign of disturbance and looks as if the pegmatite had eaten its way into place. Along the wall is about 4 feet of almost solid "A" or "herringbone" muscovite in plates as much as 5 or 6 inches across. The pegmatite is largely cleavelandite and quartz with small masses of impure lepidolite and some spodumene in crystals from a few inches to 2 feet or more long and more or less board-shaped.

A little columbite was found and there were many small lumps of cassiterite, reaching possibly a pound in weight. E. H. Bailey discovered a little pollucite here but none has been found since. It is entirely possible that more may be found should further work be done.

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Easterly and separated by only a few feet of rock is a second pit in which the top of the pegmatite was apparently barely uncovered by the scrubbing of the glaciers and parallel with the skull-shaped top are a number of curved cracks made while the formation of the pegmatite was still actively progressing. In the pit the cracks dip approximately 35° N. 55° W. A narrow inclusion of hornblende schist stands more steeply.

Along one of the cracks was (September 19, 1942) a remarkably pure lens of lilac lepidolite which as exposed along the dip was 19 feet wide, and 5 feet thick in the middle. At the upper end a few cubic feet of the lepidolite was white. In spite of the movement of solutions that replaced the quartz by this large mass of lepidolite the crack with others of the same age is still open. Buried in the lepidolite are a few crystals of spodumene of which the largest seen was about 8 inches long, 7 inches broad and 1 inch thick. Here and there are bundles 1 to 3 inches thick of tourmaline crystals 1/8 inch in diameter. Most of the bundles are 4 or 5 inches long and part have a gray or almost colorless center in the smaller end that grades into red toward the outside of the bundle and toward the other half of its length. In the quartz outside of the lens similarly colored sheaves of tourmaline 16 or 18 inches long and 8 inches in diameter have been seen. Some of them had been broken while still growing and had formed knee-shaped angles along their length. They are apparently of the same age as the lepidolite and have replaced the quartz. A quantity of the lepidolite roughly estimated as about 35 tons had been quarried and piled ready for shipment. Two or three tons more were quarried but were not yet picked over and piled.

Outside of the large lens lepidolite is scattered irregularly through the quartzose pegmatite in much smaller masses that are mostly mixed with considerable quartz and cleavelandite and are less than 2 feet long and a foot thick. Spodumene crystals as much as 3 feet long, 8 inches wide and 2 or 3 inches thick are also scattered through the quartz, with here and there small nodules of amblygonite of 1 to 3 cubic inches each surrounded by a dark envelope of pinite (muscovite in microscopic plates) about 1/8 inch thick; small masses of cassiterite so dark that it is difficult to identify with certainty by appearance, but which make a slightly purplish powder. Columbite also is scattered through the cleavelandite. It is in small radial groups of thin plates having surfaces ranging from a small fraction of a square inch to 6 or 8 square inches, and with a thickness ranging downward from 1/16 of an inch to that of paper.

Considerable scrap mica is scattered through the quartz. It is more or less radial and may be in books 3 inches broad and as thick.

Some of the mica has green tourmaline between the leaves and in places it appears to be replaced by blue tourmaline.

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Adjoining on the east is another working, the floor of which is 6 or 8 feet higher. The pegmatite is similar but much more spodumene and much less lepidolite are visible. The spodumene is very irregular in shape and size. One crystal was 3 feet long, 17 inches wide, 5/8 inch thick and like nearly all of the crystals had been very much broken by movement in the pegmatite. Spodumene is rather sparsely exposed for a length of 50 feet, 8 or 10 feet high, and through an uncertain width of possibly 40 or 50 feet. The aggregate quantity of spodumene is considerable and probably amounts to some hundreds of tons, but on account of its broken condition hand-picking is impracticable.

In the pegmatite above this working, a number of crystals of white beryl outcrop. The largest is about 8 inches in diameter but has been cracked and has been irregularly replaced along the crack by cleavelandite for a width of 1 or 2 inches.

Another opening has been made in pegmatite 30 or 40 feet above the middle pit already described from which it is separated by a few feet of schist that may be either an inclusion or a wall.

A body of buff microcline that, though comparatively thin vertically, must have contained several hundred tons, has been removed. In the course of the work a pile of white beryl containing an estimated 15 tons was accumulated. Some of the pieces show a well developed parting parallel to the basal plane. The largest crystal seen was partly covered but was about 10 inches across the base and possibly one third was replaced by cleavelandite. Part of the beryls show three or four zones of growth. In general the beryls seem to lie about perpendicular to the walls. A pile had also been made of pieces of cleavelandite containing crystals of columbite similar to those described but 4 inches to 8 inches wide and long by 1/32 inch or less thick and badly shattered. A few small reddish crystals were apparently manganocolumbite. The only signs of rare alkalis seen in the pit were blue tourmalines and small pieces of purpurite (manganese phosphate made by the weathering of lithiophilite) close to the northwest wall.

At numerous places the freshly broken feldspars and some quartz gave off a fetid odor.

Spectrochemical visual estimates of the alkalis and other elements in minerals from Black Mountain gave the following results:

	Na_2O	K_2O	Li_2O	Rb_2O	Cs_2O	Ga_2O_3
Beryl	0.5	0.2	0.5	none	0.5	1/0.01
41 Lepidolite.....	1.0	5.0	5.0	3.0	2.0	0.5
19B Feldspar	5.0	3.0	0.5	2.0	0.5	n.d.
43 Tourmaline, pink:	3.0	1.0	3.0	0.5	n.d.	1.0

1/ Gallium is barely detectible and may be less than 0.01 percent.

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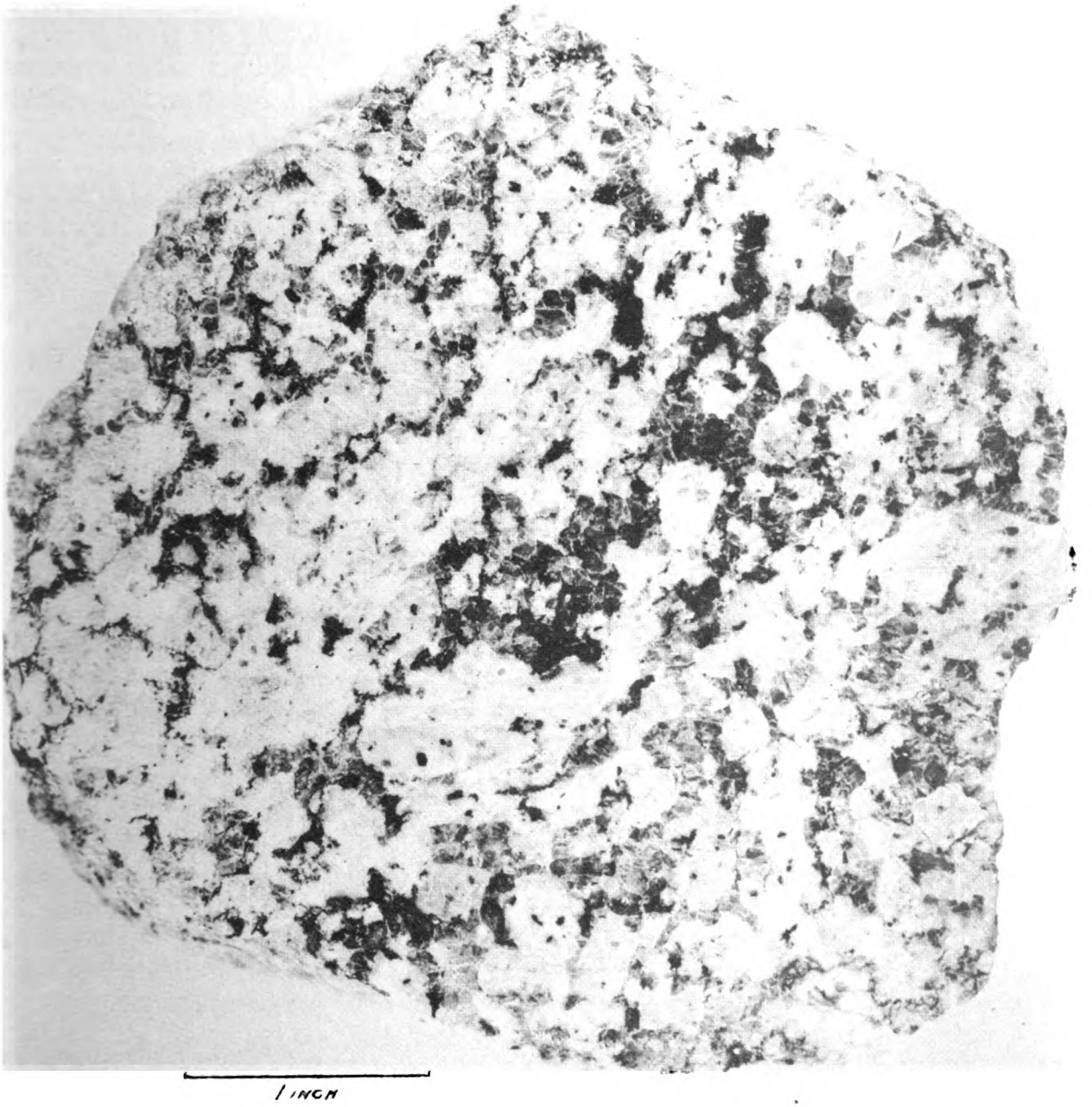

Figure 8.- Coarse granite, partly reworked, from dike 15 feet wide on Hodgeon Hill, 3 miles west of Buckfield, Maine. Photograph by Morris Slavin.

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Indium and germanium could not be found. The gallium content (1.0 percent Ga_2O_3) of the tourmaline is notable.

The lepidolite was lilac-tinted. The feldspar which looked like ordinary microcline, was a small piece from the middle pit and was intergrown with pink tourmaline, spodumene, amblygonite, and quartz.

It may be that under war-time conditions the pegmatite could be worked to advantage by taking out the whole mass, separating it by flotation and magnetic treatment, making feldspar, spodumene, beryl, scrap muscovite, columbite, cassiterite and possibly amblygonite concentrates. A market even for the quartz might be found in the glass trade. The Black Mountain and Plumbago Mountain pegmatites could be treated in the same mill.

Hodgeon Hill, Buckfield. - Hodgeon Hill in the town of Buckfield is 2 miles northeast of Streaked Mountain, about 2-1/2 miles in a direct line and about 3 miles by road southwest of Buckfield village. In it are two pegmatites that have been worked for pollucite. Perien S. Dudley discovered the mineral in these two pegmatites and in another nearer Buckfield and took out between 6,000 and 7,000 pounds previous to 1925. It was sold either to investigators for research work or to museums and collectors for specimens.

In 1925 W. D. Nevel mined the pegmatite on the east slope of the hill for the General Electric Co. Here a dike of moderately coarse granite that showed some reworking (see fig. 8) was about 15 feet wide and was readily followed about 600 feet, cutting across a coarse biotite schist. The dike had been cracked lengthwise, and solutions rising along the crack had replaced most of the granite by pegmatite containing occasional vugs. Cracks running to the sides were followed by branching and bulbous masses of pegmatite. Uneven distribution of biotite and uneven growth of the feldspars in the granite itself showed that it also had been somewhat reworked. The pegmatite consisted mostly of microcline and quartz. There was some muscovite in diamond-shaped crystals, and some was intergrown with biotite. Subsidiary minerals were cleavelandite; pink garnets (in the outer parts of the pegmatite); green apatite crystals half an inch thick; a little arsenopyrite; radial veinlets of pyrite 0.01 inch thick having black tourmalines 1/4 to 5/8 inch thick and 2 or 3 inches long at their ends continuing the radial structure; a little green and blue beryl said to contain cesium; amblygonite; cassiterite; arsenopyrite; pink montmorillonite (said to carry cesium but not tested by us); and green and dark-blue tourmalines.

The microcline was in part massive (a little of which was greenish) and in part crystals 2 to 7 inches or more through and as much as 2 feet long. The crystals were the latest of the microclines and apparently were deposited at the highest temperature.

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Pollucite was found only with the crystals of microcline. All was crushed, and some was earthy looking. One cavity from which pollucite had been taken showed a rude crystal form 6 or 7 inches across. The cavity was lined with mica (lepidolite) in plates 1/8 inch across and normal to the pollucite. Mr. Nevel said that all of the pollucite found here had a similar envelope.

About 3,00 pounds of pollucite was taken out during the first season. Mr. Dudley (according to a personal letter of W. D. Nevel) took out masses of pollucite that contained as much as 600 pounds. In 1927 one mass weighing 450 pounds and another weighing 950 pounds were taken out. The largest mass was said to have been about 6 feet long and very irregular but to have averaged 10 or 12 inches in thickness. The pegmatite was mined for a length of 300 feet to a depth of 10 to 20 feet.

Another pegmatite, known as the "lower vein" about a quarter of a mile northeast of that just described and also worked for pollucite, seemed to have the same geological characteristics, that is it also was a replacement along a crack in granite. A pit about 300 feet long, 15 feet wide, and 10 to 15 feet deep was dug, and, as in the other pegmatite, the pollucite was confined to a narrow zone of late high-temperature minerals in the middle. How much pollucite was obtained from the two pegmatites is unknown, but, including perhaps 100 or 200 pounds from other places, the General Electric Co. took from these two pegmatites and the Dunton pegmatite approximately:

	Pounds
High-grade pollucite, 20 to 25 percent Cs, ...	23,500
Medium-grade pollucite, 6 to 12 percent Cs,...	1,100
Low-grade pollucite, 0 to 6 percent Cs, ...	8,000
Total, all grades	32,600

Dudley pegmatites, Buckfield. - In the hill north of Perien S. Dudley's house, about 2 miles southwest of Buckfield, the Westinghouse Lamp Co. mined during 1927 the third pegmatite in which Mr. Dudley had previously discovered pollucite.

The pegmatite cut a coarse biotite granite, and at the time it was examined an excavation about 25 feet wide and 50 feet long had been made. In the face of the excavation the pegmatite was almost wholly an aplitic mass but was cut by two bands of cleavelandite with other late higher- temperature minerals, and it was in these bands that the pollucite was found. In fig. 9 a rough field sketch of the face of the excavation is shown. A total of about 800 pounds of pollucite was taken out by the company.

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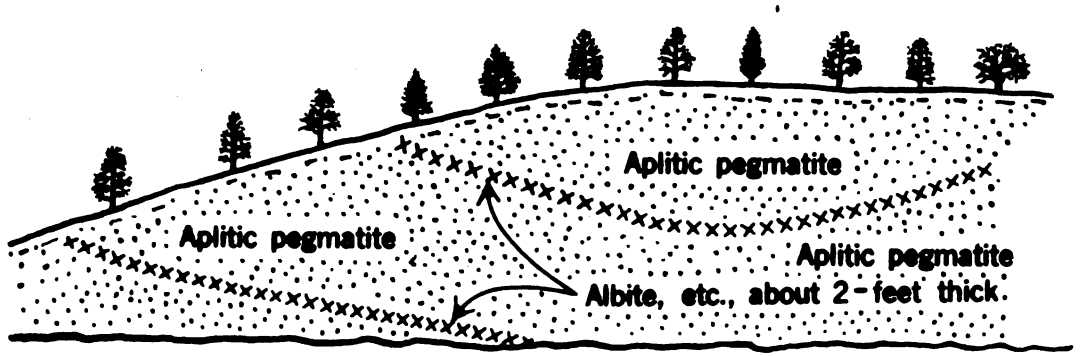

Figure 9.—Rough field sketch (October 1, 1927) of Dudley pegmatite, 2 miles southwest of Buckfield, Maine, Worked by Westinghouse Electric Co. The face is 25 feet wide. Pollucite was found in the albite replacement area.

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Owls Head, Buckfield. - During the second half of the 1920's, W. D. Nevel, agent for the General Electric Co., worked a pegmatite on Owls Head, a hill 2-1/2 miles S.,15° to 20° W. of the village of Buckfield, but results are unknown. (Personal communication from E. M. Bailey, dated April 29, 1941.) In 1941 a discovery of pollucite on the same hill was announced, but whether in the same pegmatite is also unknown.

Uncle Tom Mountain, Greenwood. - Uncle Tom Mountain, 1,700 feet high, is about the middle of the southwest line of the town of Greenwood and is a little more than 2-1/2 miles west of the village of the same name, 8 miles west of West Paris, and 5-1/2 miles southwest of the village of Bryant Pond. By road the distances are longer, of course.

In 1931 the Oxford Mining & Milling Co. (now United Feldspar & Minerals Corporation) operated a quarry for potash feldspar in a pegmatite on the Emmons farm, on the east side of the mountain. The face of the quarry was about 20 feet wide and 25 feet high. The feldspar was in large bodies in which replacement was not prominent, nevertheless, in a comparatively small body that had been replaced along cracks in the feldspar a mass of pollucite was found from which a total of 4,638 pounds containing 29 percent Cs_2O was obtained. (Personal communication from J. H. Weis.) It must have been very irregular in shape, because it was said to have been 3 feet in diameter and 16 feet in length and such a body of regular shape would contain about 10 tons. (Personal communication from W. D. Nevel.) It enclosed one pink beryl that was almost equidimensional and 12 to 16 inches through. Most of the pollucite was glassy, though crushed, but part was kaolinized. Some spodumene was found but little if any lepidolite. Since then no pollucite has been found in this pegmatite.

Noyes Mountain, Greenwood. - At the Tamminen feldspar quarry at the foot of Noyes Mountain near the Norway-Locks Mills road, also operated by the United Feldspar & Minerals Corporation, some pollucite has been found, but it was badly weathered, and the cesium content was very low. (Letter of J. H. Weis.) The quarry has been exhausted.

In another pegmatite quarried by the Oxford Mining & Milling Co. at the foot of Noyes Mountain, and "a few hundred feet" south of the Tamminen quarry, pollucite was found with petalite, as it was where first discovered on the Isle of Elba. Richmond and Gonyer[33/] found that the pollucite replaced the petalite, a replacement not elsewhere noted. They also found

33/ Richmond, W. E., and Gonyer, F. A., On Pollucite: Am. Mineral., vol. 23, 1938, pp. 783-789.

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tiny crystals of pollucite ranging from 2 to 4 mm. on an edge, in a small vug - the only occurrence of pollucite crystals known in America. They determined the following constants for pollucite from Greenwood and other localities in Maine:

Refractive index and specific gravity of pollucite with varying content of Cs_2O and H_2O

	Hebron	Greenwood, Tamminen	Mt. Mica	Elba	Buckfield	Greenwood, crystals	Leominster[1/]
n	1.526	1.522	1.520	1.520	1.520	1.507	1.520
G.	2.98	2.97	2.94	2.90	2.90	2.68	2.89
Percent Cs_2O	36.06	35.83	-	34.30	-	24.48	33.06
Percent H_2O	1.52	1.62	-	2.40	-	3.80	2.04

1/ Richmond, W. E., and Gonyer, F. A., On Pollucite: Am. Mineral., vol. 23, 1938, pp. 783-789.

They also give the following analyses:

Comparison of analyses and theoretical compositions

	1	2	3	4	5	6
SiO_2	44.21	49.92	43.51	44.37	43.05	49.65
Al_2O_3	16.29	17.14	16.36	16.08	16.61	17.32
Cs_2O	35.78	24.46	36.06	34.30	36.76	24.03
Na_2O	2.10	4.63	2.55	2.85	2.02	5.08
H_2O	1.62	3.80	1.52	2.40	1.56	3.92
	100.00	100.00	100.00	100.00	100.00	100.00
Cs:Na=	4:1	1:1	4:1	3:1	4:1	1:1
H_2O	4	9	4	6	4	9

1. Massive pollucite, Tamminen quarry, Noyes Mountain, Greenwood, Maine.
2. Crystals of pollucite, Oxford Mining & Milling Co. quarry, Noyes Mountain.
3. Massive pollucite, Hebron. Analyst, Wells. Recalculated to 100 percent.
4. Massive pollucite, Elba. Analyst, Wells. Recalculted to 100 percent.
5. Theoretical composition, $Cs_{15}Al_{15}Si_{33}O_{96}.4H_2O$.
6. Theoretical composition, $Cs_{14}Al_{14}Si_{34}O_{96}.9H_2O$.

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They say "It is interesting to note that the amount of water is inversely proportional to the content of Cs_2O. The significance of this fact is not apparent," and they propose as a formula $Cs_{14+x}Al_{14}(Al_xSi)_{34}O_{96}.4\text{-}9H_2O$, in which x may be 0, 1, or 2. A better form is $Cs_{14+x}Al_{14+x}Si_{34-x}O_{96}.nH_2O$[34] Apparently only specimens of pollucite were found.

The authors note that the faces of a large quartz pseudomorph from the "Harvard mine" near the top of Noyes Mountain correspond to the forms found on the pollucite crystals. A number of such pseudomorphs 2 to 3 inches along an edge had been known for some years, but it is understood that none of the original mineral has been found in the pegmatite.

About 8 tons of petalite is said to have been mined from the Oxford Mining & Milling Co. property. Gonyer[35] made two analyses of the petalite with the following results:

	1.	2.
SiO_2	78.10	78.44
Al_2O_3	16.64	16.64
Li_2O	5.13	4.92
H_2O	.22	

These yield the accepted formula $Li_2O.Al_2O_3.8SiO_2$.

Cobble Hill, Norway. - In a pegmatite on Cobble Hill in the northeast corner of the town of Norway, about 3-1/2 miles southwest of West Paris, a vug was discovered in 1931 that was about 2 feet in diameter and contained clear plates of muscovite 3 inches across with a border of lepidolite 3/16 inch wide. There was also some pure lepidolite. Pollucite was found extending from the vug into the pegmatite, and about 100 pounds was extracted. (Letter of W. D. Nevel.)

Dana[36] notes the occurrence in Norway of amblygonite, beryl, chrysoberyl, rose quartz, green tourmaline, albite, triphylite, lithiophilite, cookeite, and cassiterite, to which Bastin[37] adds black tourmaline, gahnite, and zircon.

34/ Fleischer, Michael, and Ksanda, K. S., Hydration of Pollucite: Am. Mineral., vol. 25, 1940, p. 665.

35/ Work cited in footnote 33.

36/ Dana, J. D., and Dana, E. S., The System of Mineralogy: 6th ed., 1892, p. 1055.

37/ Bastin, Edson S., Geology of the Pegmatites and Associated Rocks of Maine: U. S. Geol. Survey Bull. 445, 1911, p. 78.

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Hebron. - Hebron has long been a happy hunting ground for mineralogists, so that although its minerals have not been very important commercially, they have had considerable notice in the literature.

P. D. Allen,[38] knowing that rubidium and cesium had been found in European lepidolite, examined the mineral from Mount Rubellite, 1-1/2 miles northeast of Hebron village, where, as at Penig, Saxony (at the time a noted locality), it occurred with amblygonite (at one time called hebronite), red and green tourmaline, and albite (cleavelandite). He found the percentages of the two alkalis to be very small - 0.14 Rb (0.15 Rb_2O) and 0.3 Cs (0.32 Cs_2O) and the lepidolite is remarkable in that according to these determinations the cesium is in larger quantity than the rubidium.

Coarsely granular, purple lepidolite from the same pegmatite was analyzed by R. B. Riggs,[39] but the potassium, rubidium, and cesium were not separated. The analysis is quoted with those of other Maine lepidolites, also by Riggs in the following table:

Analyses of lepidolites from Maine
(R. B. Riggs, analyst)

	Rumford, purple	Paris, foliated	Hebron, granular	Auburn		Norway	
				Border	Granular	White	Brown
SiO_2	51.52	50.92	48.80	49.62	51.11	49.52	50.17
Al_2O_3	25.96	24.99	28.30	27.30	25.26	28.80	25.40
Fe_2O_3	.31	.30	.29	.31	.20	.40	.87
FeO	(1/)	.23	.09	.07	.07	.24	.45
MnO	.20	(2/)	.08	.55	.17	.07	.23
CaO	.16	(2/)	.10	-	.12	.13	(1/)
MgO	.02	(2/)	.07	-	.01	.02	(1/)
Li_2O	4.90	4.20	4.49	4.34	4.98	3.87	4.03
Na_2O	1.06	2.11	.74	2.17	1.43	.13	
K_2O	11.01	11.33	}	8.03	10.51	8.82	} 13.40
Rb_2O	-	(2/)	} 12.21	2.44	1.29	3.73	
Cs_2O	-	(2/)	}	.72	.45	.08	
H_2O	.95	1.96	1.73	1.52	.94	1.72	2.02
F	5.80	6.29	4.96	5.45	6.57	5.18	5.05
	101.89	102.38	101.86	102.52	103.11	102.71	101.62
Less oxygen	2.44	2.64	2.02	2.29	2.76	2.18	2.13
	99.45	99.74	99.84	100.23	100.35	100.58	99.49

1/ Undetermined.
2/ Trace.

38/ Allen, P. D., Observations on Cesium and Rubidium: Am. Jour. Sci., ser. 2, vol. 34, 1862, pp. 367-373.
39/ Clarke, F. W., Researches on the Lithia Mica: U. S. Geol. Survey Bull. 42, 1887, p. 19.

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Clarke[40] notes that some of the rubellite was altered to damourite (muscovite). In 1891 Loren B. Merrill[41] discovered in the same pegmatite about a pound of pollucite in the "sand" at the bottom of two vugs. As already stated, this was the first found after the initial discovery on the Island of Elba in 1846. It was analyzed by H. L. Wells,[42] with the results shown in the following analysis:

Analysis of pollucite from Hebron, Maine
(H. L. Wells, Analyst)

	Percent
SiO_2	43.51
Al_2O_3	16.30
Li_2O	.05
Cs_2O	36.10
K_2O	.48
Na_2O	1.68
CaO	.22
H_2O less at red heat	1.50
	99.84
Specific gravity	2.986

Colorless beryl from the same pegmatite was analyzed by Penfield,[43] and he found that "The beryl contains more cesium than the lepidolite in which it is imbedded;" in fact, it contains more cesium than any known mineral except pollucite. He also made analyses of beryl from two other localities in Maine, one in Connecticut, and one in Massachusetts, with the following results in percent:

40/ Clarke, F. W., Work cited in footnote 39, pp. 354-355.
41/ Wells, H. L., On the Composition of Pollucite and Its Occurrence at Hebron, Maine: Am. Jour. Sci., ser. 3, vol. 41, 1891, pp. 213-220.
42/ Wells, H. L., Work cited in footnote 41, p. 219.
43/ Penfield, S. L., On the Occurrence of Alkalies in Beryl: Am. Jour. Sci., ser. 3, vol. 25, 1884, pp. 28-29.

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	I Hebron, Maine	II Norway, Maine	III Stoneham, Maine	IV Branchville, Conn.	V Royalston, Mass.
SiO_2	62.10	64.29	65.20	64.74	65.14
Al_2O_3	18.92	18.89	20.25	20.13	19.83
FeO	.49	.48	.66	.54	.78
BeO	10.35	10.54	11.46	10.26	11.32
Cs_2O	2.92	1.66	-	-	-
Na_2O	1.82	1.39	.49	1.45	.51
Li_2O	1.17	.84	trace	.72	.05
Ignition	2.33	2.44	2.08	2.69	2.04
CaO	.35	-	-	-	-
MgO	-	-	-	-	.34
Fe_2O_3	-	-	-	-	.44
	100.45	100.53	100.14	100.53	100.45
Specific gravity	-	2.744	2.708	2.732	2.711

I. From Hebron, Maine. - The material was taken from a fragment of a very much cracked, colorless crystal imbedded in lepidolite.

II. From Norway, Maine. - The material was milk-white and did not outwardly resemble beryl, the fragments in my possession showing no crystal faces.

III. From Stoneham, Maine. - The material was perfectly transparent and taken from fragments of a pale-green crystal.

IV. From Branchville, Conn. - The material was taken from a fragment of a beautiful, large, pale sea-green crystal much resembling a piece of slightly colored quartz.

V. From Royalston, Mass. - From a bluish-green crystal from which pure, transparent material could readily be obtained.

It seems to be commonly believed in Maine that only the pink beryl contains cesium, but one of these cesium-bearing beryls was colorless and the other was white.

It is remarkable that the beryls contained lithium, cesium and sodium, but no rubidium nor potassium; analyses of colored tourmalines show all of the alkali metals except cesium; microcline may contain 2 or 3 percent each of rubidium and cesium, but no more than a fractional percentage of lithium; and none of the lithium minerals, except lepidolite, carry more than small fractions of a percent of either rubidium or cesium.

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Penfield[44] also analyzed cookeite that replaced rubellite in the same pegmatite. He found that when heated the mineral "exfoliates prodigiously, like vermiculite." The mean of two analyses was as follows:

Mean of two analyses of cookeite from Hebron, Maine (S. L. Penfield, analyst)

	Percent
SiO_2	34.00
Al_2O_3	45.06
Fe_2O_3	.45
CaO	.04
K_2O	.14
Na_2O	.19
Li_2O	4.02
H_2O	14.96
F	.46
	99.32
O equivalent to the F	.19
	99.13

Besides the minerals already noted, Bastin[45] recorded apatite, arsenopyrite, cassiterite, childrenite, halloysite, and herderite in the pegmatite.

In 1928 Merrill, acting for the General Electric Co., again worked the pegmatite in a search for pollucite, but, in spite of the probability indicated by the cesium-bearing minerals already taken out, none is known to have been found.

No spodumene has been noted, and the total quantity of rare alkali minerals is small.

A half mile east of Hebron Academy, near the Cushman farm, a little pollucite of gem quality was obtained by W. D. Nevel (Personal communication, Dec. 8, 1931).

From spectrographic examination of a light-colored microcline from the "Hibbs Ledge," 1-1/2 miles north of Hebron village, the following

44/ Penfield, S. L., On Cookeite from Paris and Hebron, Maine: Am. Jour. Sci., ser. 3, vol. 45, 1893, pp. 395-396.

45/ Bastin, Edson G., Geology of the Pegmatites and Associated Rocks of Maine: U. S. Geol. Survey Bull. 445, 1911, p. 74.

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visual estimates were made: K_2O, 5.0; Na_2O, 5.0; Li_2O, 0.2; Rb_2O, 3.0; Cs_2O, 1.0.

Among the specimens examined, this feldspar was equalled in rubidium content only by that from the Dunton quarry, Town of Newry, Maine, and in cesium content only by those from the Dunton quarry, from West Chesterfield, Mass., and from Cogshall Park, Fitchburg, Mass.

Although considerable quarrying was done for feldspar, no lithium or cesium minerals except a little lepidolite are known to have been found in the pegmatite. How much feldspar may be left in the pegmatite is uncertain.

Minot. - In the southeastern part of the town of Minot, a little more than half a mile north of Haskell Corner (on the road between Auburn and Minot village and about 3 and 1-1/2 miles, respectively, from them), on the south side of Mount Apatite, is the quarry of the Maine Feldspar Co., in which a little pollucite, spodumene, amblygonite, and lepidolite are reported to have been found.

Some lithium minerals have been reported from other large quarries in pegmatites in the same neighborhood but have not been seen by the writers. Two analyses by Riggs, entitled Auburn (see p. 28), are thought to have been made on lepidolite from one of these pegmatites.

Mount Mica, Paris. - The first well-known Maine pegmatite was discovered in 1820.[46] on Mount Mica about 1-1/2 miles northeast of the village of Paris. In a pegmatite that forms the crest of the hill, the solution by late flows of hot fluids had been greater than the deposition from them, so that many vugs had been formed in which colored tourmalines, some of great beauty, had crystallized, and the vugs had preserved them from crushing by the later movements of the rocks. For a number of years the pegmatite was quarried for the tourmalines.

As already noted, the occurrence of lepidolite and red tourmaline at Paris was recorded in the first edition of Dana's Mineralogy.[47] Later, the pegmatite was worked for feldspar, the lepidolite encountered was saved, and, about 1925, 38 tons was reported as sold for its cesium and rubidium content, although in the analyses made by Riggs (see p. 28) he found only traces of the two elements. Two specimens kindly furnished by

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46/ Hamlin, A. C., The History of Mount Mica of Maine, U. S. A.: Privately published, Bangor, Maine, 1895, p. 7.

47/ Dana, J. D., A System of Mineralogy: New York, 1837, p. 264.

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H. G. Savage and F. V. Johansson, both of Leominster, Mass., were tested spectrochemically, and the following estimates were made of the alkali metals and gallium:

	Na_2O	K_2O	Li_2O	Rb_2O	Cs_2O	Ga_2O_3
Savage	5.0	1.0	5.0	3.0	1.0	0.5
Johansson	5.0-10.0	1.2	5.0	2-3	.5	.01

The specimens contained no indium or germanium. As will have been seen, the quantities of the rare alkali metals indicated are much larger than those found by Riggs (see p. 28) and are probably more nearly correct, as shown by the fact that the lepidolite was sold for its rubidium and cesium content.

In 1910, Loren B. Merrill took out 800 pounds of pollucite (according to a letter from Howard M. Irish of Buckfield, Maine, Aug. 28, 1940), but none has been found since. Other minerals of the pegmatite were triphylite, amblygonite, spodumene, cookeite, black tourmaline (one crystal of which was 4 feet long; thickness not given[48]), rose and crystallized quartz, cassiterite, apatite, columbite, zircon, brookite, beryl, and löllingite.

Other localities. - Spodumene has been reported as in considerable quantity in two pegmatites west of Kezar Pond; town of Fryeburg; at Litchfield; Peru (with amblygonite, petalite, and triphylite); Wilton; and Windham. Lepidolite has been reported at Georgetown and Standish, and amblygonite with lithiophilite at Poland.[49] An analysis of the lithiophilite by Gonyer[49] gave:

Analysis of lithiophilite from Poland, Maine
(F. A. Gonyer, analyst)

	Percent
FeO	10.96
MnO	31.90
Na_2O	.30
Li_2O	9.55
P_2O_5	46.35
H_2O+	.40
Insol.	.16
Total	99.62

48/ Hamlin, A. C., Work cited in footnote 46, p. 7.
49/ Berman, Harry, and Gonyer, F. A., Pegmatite Minerals of Poland, Maine: Am. Mineral., vol 15, 1930, pp. 375-387.

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J. H. Weis and Prof. Charles Palache courteously supplied us with specimens of feldspars from various Maine pegmatites besides those mentioned in the text, and they have been tested spectrographically for the alkalis, germanium, indium, and gallium. They are marked W (Weis) and P (Palache) to show the donor; n.d. = too little to be determinable.

		K_2O	Na_2O	Li_2O	Rb_2O	Cs_2O	Ga_2O_3
1.	Cloutier quarry, Mount Apatite, 2 miles west of Auburn (W)	5	5	n.d.	0.5	n.d.	n.d.
2.	Mount Apatite (P)	5	5	0.1	.5	0.1	n.d.
3-4.	Bumpus quarry, 7 miles south of Bethel (W)	5	5	n.d.	.5	n.d.	n.d.
5.	N. E. Bessey quarry, 3 1/2 miles west of Buckfield (W)	5	5	n.d.	0.5	n.d.	0.1
6.	Bennett quarry, 3 1/2 miles west of Buckfield (P)	5	5	0.2	2.0	1.0	.1
7.	Jas. Williams quarry between Danville and Pownal (W)	2	2	n.d.	.2	n.d.	.1
8.	Roy Wardwell quarry, East Stoneham (W)	5	5	n.d.	1.0	0.2	.1
10.	Mount Rubellite, 1 mile north 15° east of Hebron.	2	5	.2	.5	n.d.	.1
11.	Atwood Kimball quarry, Slab City (W)	5	7.5	n.d.	.5	n.d.	.1
12.	Walter Cooke quarry, Slab City (W)	5-10	5-10	n.d.	1.0	0.1	.1
13.	F. Conroy quarry between Mechanic Falls and West Minot (W)	5	5	n.d.	.5	n.d.	.1
17.	Anderson quarry, Chas. Chaplin Farm, North Lovell (W)	5	5	n.d.	1.0	n.d.	.1
18.	Piatella quarry, 2 miles east of Paris Hill (W)	5	5	n.d.	.5	n.d.	.1
19.	Twitchell quarry, west side of Paris Hill (W)	5	5	n.d.	.2	n.d.	.1
19A.	Twitchell quarry, west side of Paris Hill (W)	5	5	n.d.	.5	n.d.	.1
20.	Topsham (P)	5	5	n.d.	.5	n.d.	.1
21.	Mason quarry, Peabody Mountain, West Bethel (W)	5-10	5-10	n.d.	1.0	0.1	.1
22.	Benson quarry, 2 miles north of West Paris (W)	5-10	5.0	n.d.	1.0	n.d.	.1

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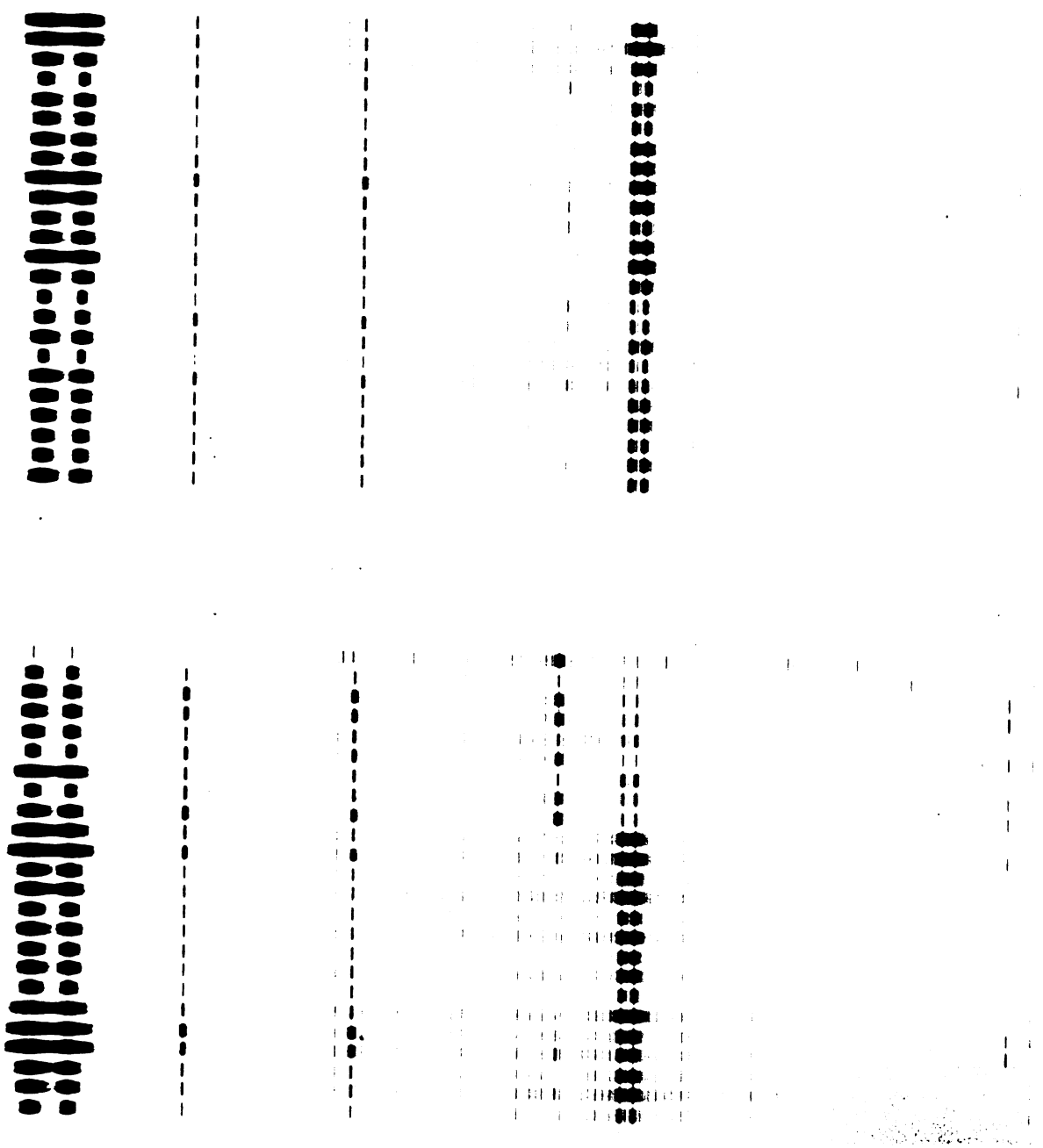

Figure 10.- Spectrographic lines on which are based estimates of the alkalis. Spectrographic work by Morris Slavin.

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	K_2O	Na_2O	Li_2O	Rb_2O	Cs_2O	Ga_2O_3
23. Benson quarry, 2 miles north of West Paris (W)	3	2	n.d.	.5	n.d.	.1
24. A. C. Perham, 2 miles south of West Paris (W)	5	3	.1	1.0	n.d.	.1
24A. D. S. Briggs pegmatite, Wilton	5	3	n.d.	1.0	n.d.	.1
40. Lepidolite, Bennett quarry, 3-1/2 miles west of Buckfield, Maine	5	1	5.0	2.0	2.5	.5

The accompanying plates (see fig. 10) show the type of spectrographic lines on which these and other estimates are based.

Massachusetts

Foreword. - Although the first notice of lithium minerals in the Western Hemisphere described spodumene from the town of Sterling and "the vicinity of Deerfield,"[50/] Mass., none is known to have been produced or sold from the State, except for specimens. However, should a lively demand for lithium minerals be developed, as seems to be a reasonable possibility, the State could supply a considerable quantity of spodumene and some lepidolite. A large number of printed papers have described the lithium minerals of Massachusetts, but many have naively omitted exact reference to localities, even in areas where pegmatites are plentiful, and have avoided reference to quantities.

Leominster. - The town of Sterling lies a mile or so south of the edge of the city of Leominster, and the spodumene discovered was in a glacial boulder, of which there are many. One such boulder lying 2 miles southwest of Leominster has an exposed mass that is about 15 by 15 by 30 feet. It is so large that for a good many years it was not recognized as being unattached. In 1937 Roscoe J. Whitney followed the spodumene-bearing boulders in the drift for about 4 miles to the south and a mile north of the big boulder.

On the north, at the foot of Long Hill, he found a pegmatite lens with similar structure and minerals and almost on a level with the broad valley in which the big boulder rests. The pegmatite is enclosed in gray sericitic schists, and both have been planed smooth by the glaciers, the pegmatite bulging only a little above the schist. In places the schists are graphitic.

50/ Nuttall, Thomas, Notices of American spodumene: Philadelphia Academy of Natural Sciences, Journal: Vol. 3, pt. 2, 1824, pp. 284-286.

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The pegmatite is lenticular in horizontal cross section, about 25 feet wide at most and a little longer than wide. It is white and contains rather small masses of microcline 2 or 3 inches in diameter, quartz, and a small quantity of muscovite. Through the aggregate are distributed crystals of spodumene from an inch or two to possibly a foot or more long, probably mostly one-fourth to one-third as thick as long. The pegmatite contains possibly 10 to 15 percent of spodumene.

Up the hill from this outcrop is another pegmatite in which a little blasting has been done. Here the pegmatite is in the edge of a somewhat gneissoid, small porphyritic, highly biotitic granite that forms the country rock on the west. The exposure is about 20 feet wide and is somewhat longer than wide. Part of the lens is albite aplite.

Except for the aplite, which contains none, the spodumene content is about as in the other lens. In the places where there is spodumene the feldspar and mica have been partly or wholly replaced by quartz and spodumene (see fig. 11) much as Nuttall[51/] first described it:

> The spodumene occurs on the farm of Mr. Putnam, in Sterling, Mass., where it is found abundantly in a granitic rock composed principally of hyaline quartz, and mica, the spodumene supplying the place usually occupied by feldspar. It occurs in lamellar masses of white color and pearly luster.

In both pegmatites some of the spodumene is limpidly clear.

A little amblygonite in masses 1 to 3 inches thick, grains of pollucite the size of cherries, a very little lepidolite, dainty blue albite, apatite, obscure carbonates, autunite, columbite, and cassiterite are scattered through the spodumene-bearing pegmatites. There are many small, green tourmalines, some that are blue, and some that have a blue core and a green shell. Were the exposures better, it would probably be possible, as in other pegmatites, to connect these minerals with old lines of cracking.

W. E. Richmond[52/] examined the pollucite occurrence and says that apparently the feldspars and quartz are replaced by spodumene, which in turn is altered to pollucite.

51/ Nuttall, Thomas, Notices of American Spodumene: Jour. Philadelphia, Acad. Nat. Sci., vol. 3, pt. 2, 1824, p. 285.

52/ Richmond, W. E., and Gonyer, F. A., On Pollucite: Am. Mineral., vol 23, 1938, pp. 788-789.

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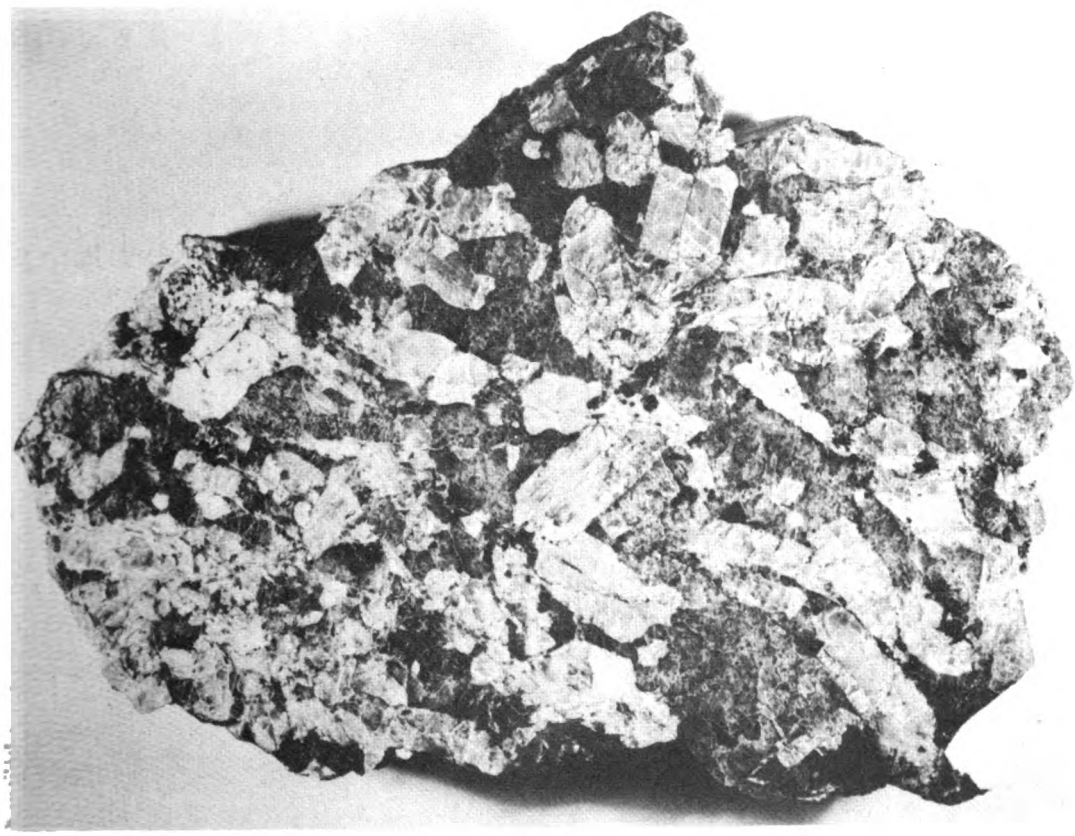

Figure 11.- Spodumene and quartz with blue tourmalines 11 by 15 inches in dimensions. Long Hill, Leominster, Mass.

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Such pollucite as was seen by the writers was indefinite as to genetic succession.

Gonyer's analysis was:

Analysis of pollucite from Leominster, Mass. recalculated to 100 percent

SiO_2	45.20	45.25
Al_2O_3	16.98	17.00
Cs_2O	33.02	33.06
Na_2O	2.04	2.04
K_2O	.61	.61
H_2O	2.04	2.04
	99.89	100.00

Constants are given in the section on Noyes Mountain, Greenwood.

Several larger lenses and a series of smaller lenses that have not been well exposed outcrop on Long Hill within half a mile to the north. Here and there small stringers of pegmatite 2 or 3 inches thick cut across the schist, and in it pink andalusite is developed for a few inches along the sides of the pegmatite.

The pegmatites as a whole undoubtedly contain a good many carloads of spodumene-bearing rock. The float boulders alone probably would furnish 500 to 1,000 tons carrying 10 to 15 percent of spodumene. Although some pollucite has been found, the grain of the pegmatites is so moderate that the outlook for masses of pollucite can hardly be considered to be good.

In the spring of 1941, John H. Brodrick discovered an outcrop of similar spodumene-bearing pegmatite on the Leominster-Sterling town line between 100 and 200 yards east of the big glacial boulder described, and, although contacts are not wholly clear, it seems to be in place. It contains blue tourmaline, columbite, and cassiterite but as now known has little commercial importance.

Fitchburg. - In 1939 Mr. Whitney found spodumene in a pegmatite at the north end of Pine Hill in Cogshall Park, Fitchburg, Mass., about 100 yards northeast of the south end of the lake. The pegmatite is of moderate grain size, strikes nearly north, is about 10 feet thick and more than 300 feet long, and has walls of very dark, gneissoid, moderately fine-grained biotite granite. It is 4 miles N. 10° W. from the spodumene pegmatites of Long Hill.

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At the north end of the Cogshall Park pegmatite as it is now exposed, a vein-shaped replacement mass of quartz and spodumene, with some feldspar, is 1-1/2 to 3 feet thick and has been uncovered for 8 to 10 feet. A little beryl and purpurite were found a short distance away, and 100 feet south muscovite books are 1-1/2 inches thick and 8 inches on an edge. Two hundred feet south the pegmatite contains grayish, decayed spodumene in a spot 2 to 3 feet across. Possibly 300 feet from the north end and about a foot from the west side irregular, greenish-white beryls 1 to 3 inches in diameter are found along an old healed adjustment crack in the pegmatite, along which they appear here and there for 50 feet.

A piece of microcline intergrown with spodumene at the north end of the pegmatite was tested spectrochemically by Morris Slavin, who estimated that it contained:

	Percent
K_2O	10.0
Na_2O.....	3.0
Li_2O	.5
Rb_2O.....	2.0
Cs_2O	2.0
Ga_2O_3 ...	.1

The cesium content is remarkable and is the highest known in microcline. The quantities exposed are not important, but as the pegmatite is in a park it would not be exploited even if otherwise it might be commercially practicable.

In the fall of 1940 a blast in a pegmatite about a mile south of that in Cogshall Park exposed some triphylite and purpurite.

Goshen. - The village of Goshen in the town of the same name is made up of a scattered row of houses on both sides of a road following the crest of a broad-topped ridge about N. 20° W. The village is about 14 miles northwest of Northampton.

The second discovery of spodumene in the Western Hemisphere apparently was made in the town of Goshen, although before the mineral was recognized as spodumene Hitchcock[53/] described it as augite "in granite,

53/ Hitchcock, Edward, A Sketch of the Geology, Mineralogy, and Scenery of the Region Contiguous to the River Connecticut; and Occasional Botanical Notices: Am. Jour. Sci., vol. 6, 1823, p. 225.

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in greenish-gray prisms sometimes 8 inches long and 2 inches wide. This locality is 1 mile north of the meeting house on the road to Ashfield." After a second visit, he said that he found it "in immense abundance in crystals 12 to 18 inches long, 3 or 4 inches wide," and that "every cabinet in the world might be supplied,"[54] thus approaching a quantitative estimate.

Twenty-seven years later Dana[55] found that spodumene is a pyroxene - the family of minerals to which augite belongs.

Hitchcock found what he thought was augite in granite the same year that Nuttall[56] found spodumene in Sterling and noted that George Bowen[57] had discovered the same mineral "in a collection of minerals from the vicinity of Deerfield, Massachusetts." Bowen says after referring to the Sterling mineral:

> I discovered several specimens of the spodumene among a small collection of minerals from the vicinity of Conway, Massachusetts.

Hitchcock was principal of a school at Deerfield, about 12 miles from the Goshen locality, which in turn is probably not more than a mile from the Conway line, and the specimens Bowen saw were probably those collected by Hitchcock, who the next year announced the identity of the minerals.[58]

The Ashfield road running north from Goshen still exists, and on the west side of the road, 2 miles from the middle of the village, is a smoothly round-topped hill on which were once a farmhouse and an apple orchard. Over an area of perhaps 2 or 3 acres are scattered many subangular boulders of spodumene-bearing pegmatite, somewhat stained by manganese dioxide from decaying garnets and carrying possibly 10 percent of spodumene. Some of the spodumene is replaced by cymatolite as noticed by Julien[59] more than 60 years ago.

54/ Hitchcock, Edward, A Sketch of the Geology, Mineralogy, and Scenery of the Region Contiguous to the River Connecticut; and Occasional Botanical Notices: Am. Jour. Sci., vol. 7, 1824, p. 285.

55/ Dana, J. D., Spodumene: Am. Jour. Sci., 2d ser., vol. 10, 1850, pp. 119-120.

56/ Nuttall, Thomas, Notices of American Spodumene: Jour. Philadelphia Acad. Nat. Sci., vol. 3, pt. 2, 1824, p. 285.

57/ Bowen, George, Analysis of a Siliceous Hydrate of Copper from New Jersey, With a Notice of the Discovery of Two Localities of Spodumene in the United States: Am. Jour. Sci., vol. 8, 1824, pp. 120-121.

58/ Hitchcock, Edward, Notice of Several Localities of Minerals in Massachusetts: Am. Jour. Sci., vol. 9, 1825, p. 20.

59/ Julien, Alexis A., On Spodumene and Its Alterations, From the Granite Veins of Hampshire County, Mass.: Ann. New York, Acad. Sci., vol. 1, 1878, p. 319.

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Whether any of the pegmatite is in place is uncertain. If it is, the largest outcrop is not more than 5 or 6 feet thick and 30 or 40 feet long.

This is evidently the locality from which the specimens mentioned by Bowen, Nuttall and Hitchcock came.

Probably more than 200 tons of the spodumene-bearing boulders could be picked up.

Two and a half miles northwest of Goshen, is the post office of Lithia - a house set in a triangle formed by the forking of Route 112 as it joins Route 9.

About a mile north of Lithia, on Route 112, is the Barrus farm, also a long-known locality for spodumene.

Possibly 300 yards east of the house is a steep ravine, along which the country rock is a lead-gray ottrelite sericite schist that dips about 45° E.

At the top of the northwest side of the ravine a pegmatite 4 feet thick is exposed for 30 or 35 feet and seems to follow the schistosity. It is of moderate grain, and the largest individual minerals seen (quartz) were 4 to 6 inches across. The large minerals are all nearly white, but the rock is so lichen-covered that most of it appears to be dull gray.

At the south end the pegmatite contains many long, narrow crystals of spodumene, a half-inch to an inch thick by 4 to 8 inches long, about parallel to the walls and strike of the pegmatite. In general they are light greenish-yellow, though some are nearly white. A few are more distinctly green, and a few are nearly clear and glassy. Spodumene was not seen in much of the pegmatite.

About 100 feet north along the ravine is another exposure of pegmatite 3 to 4 feet thick and about 20 feet long, in which spodumene crystals of about the same size lie at right angles to the wall.

In both pegmatites, indicolite (the blue tourmaline), from a small fraction of an inch to two-thirds of an inch in diameter and 2 or 3 inches long have grown through the spodumene and other minerals; there are also green tourmalines and a few zoned with several colors.

Here and there are clear, glassy, cracked minerals as large as the end of one's thumb. In a shadow they appear colorless but in good light may

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show a faint green tint. These are goshenite, defined by Shepard as "white, bluish, greenish, or pale rose-colored, transparent, translucent" beryl.[60] There is also some light-yellow beryl, both near the walls and through the middle of the pegmatites. It was at this place that "cymatolite" was found and afterwards named by Shepard.[61]

Boulders found in a small branch ravine carry a little pink tourmaline and a pink muscovite that carries a little lithia.[62]

So far as can be estimated from the outcrops, probably less than 100 tons of spodumene could be quarried.

On the same farm is another white pegmatite about half a mile east of those just described. It is reached by a gravel road that runs north from Route 9 half a mile east of Lithia post office. The pegmatite is on the west side of the road and three-fourths of a mile from Route 9. It forms the apex of a small hill above which it stands 10 to 15 feet, is 10 to 20 feet wide and 200 feet long, and appears to be rather quartzose. Thick lichens make recognition of minerals difficult. Masses of white microcline are 8 to 10 inches or possibly more in diameter, and white mica plates reach an inch across. Near the walls, scattered decayed garnets, many less than 1/4 inch in diameter, have furnished manganese oxide to stain the pegmatite somewhat.

Blue tourmaline is present, seemingly in less quantity than in the smaller pegmatites. Yellowish-white spodumene forms pencils 1/2 inch thick by 8 inches long and blades 4 inches wide and a foot long, some of which are less than 1/4 inch thick. Some crystals are altered to silky cymatolite. In places spodumene forms 20 to 30 percent of the mass. In other places little or none could be seen, and no adequate idea of the general tenor of the pegmatites could be obtained.

In places the spodumene crystals have grown along cracks, and when a chunk of rock showing crystals lying in a face is cut through, it is found that these were only spodumenes. Here, too, much of the spodumene-bearing rock has had the feldspar and mica replaced by quartz. After the spodumene was formed, cracking took place again; and later solutions,

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60/ Shepard, Charles U., A Treatise on Mineralogy: Part 1, 2d ed., 1844, p. 143.

61/ Dana, J. D., and Brush, George J., A System of Mineralogy: 5th ed., 1884, p. 456.

62/ Mallet, J. W., On the Rose-colored Mica of Goshen, Massachusetts.: Am. Jour. Sci., ser. 2, vol. 23, 1857, p. 180. He found the following alkalis in the mica: K_2O, 9.08; Na_2O, 0.99; and Li_2O, 0.64.

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following cracks across the crystals, have eaten away adjacent parts and replaced them with quartz (see fig. 12), just as has been described in the spodumene deposits near Kings Mountain, N. C.[63] Some of the cracks have never been entirely healed.

Although data for an estimate of the quantity of spodumene available are insufficient, it seems probable that more than a thousand tons of rock carrying 10 to 15 percent of spodumene could readily be quarried.

West Chesterfield. - Across the Westfield River and about half a mile east of the West Chesterfield post office, a long-known pegmatite outcrops on the point of Isinglass Hill. It is north of an about 230 feet above Route 243 and is 4-1/2 miles S 20° W. from the Barrus deposit at Lithia.

The pegmatite is about 20 feet wide and 300 feet long. A small excavation in the end of the pegmatite appears to be old and is apparently where Julien worked in 1871.[64] He referred to the locality as Chesterfield Hollow and says:[65]

> I found a small and long-abandoned opening and reopened and excavated it during portions of three successive summers. The spodumene was here found almost althogether in the form of well-defined crystals, often thickly grouped and traversing the smoky quartz in every direction, and showing all the stages of alteration into cymatolite from a mere enveloping film as an outer crust and also dulling internally the luster of its prominent cleavage surfaces to a pseudomorphous alteration of the entire crystal. Many of its crystals must have been of unprecedented and enormous size, as they were found mostly in the altered condition up to a length of 35 inches, actually measured while lying in the vein, and with a diameter which sometimes reached 10 or 11 inches.

Julien also found albite, beryl, columbite, autunite, and microlite. They formed a local replacement in the pegmatite, and few such minerals are to be found exposed in the remaining length of approximately 300 feet.

63/ Hess, Frank L., The Spodumene Pegmatites of North Carolina: Econ. Geol., vol. 35, 1940, pp. 953-957, figs. 5 and 6.

64/ Julien, Alexis A., On a Supposed New Mineral from Chesterfield, Massachusetts.: Am. Chem., vol. 1, 1871, p. 300.

65/ Julien, Alexis A., On Spodumene and Its alterations From the Granite Veins of Hampshire County, Massachusetts.: Ann., New York Acad. Sci. vol. 1, 1877-1880, p. 320.

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Figure 12.- Spodumene and quartz from Barrus farm, 2 1/2 miles northwest of Goshen, Mass., 11 by 20 inches in dimensions. Partly healed cracks, along which the crystals of spodumene have been partly removed, show at several places.

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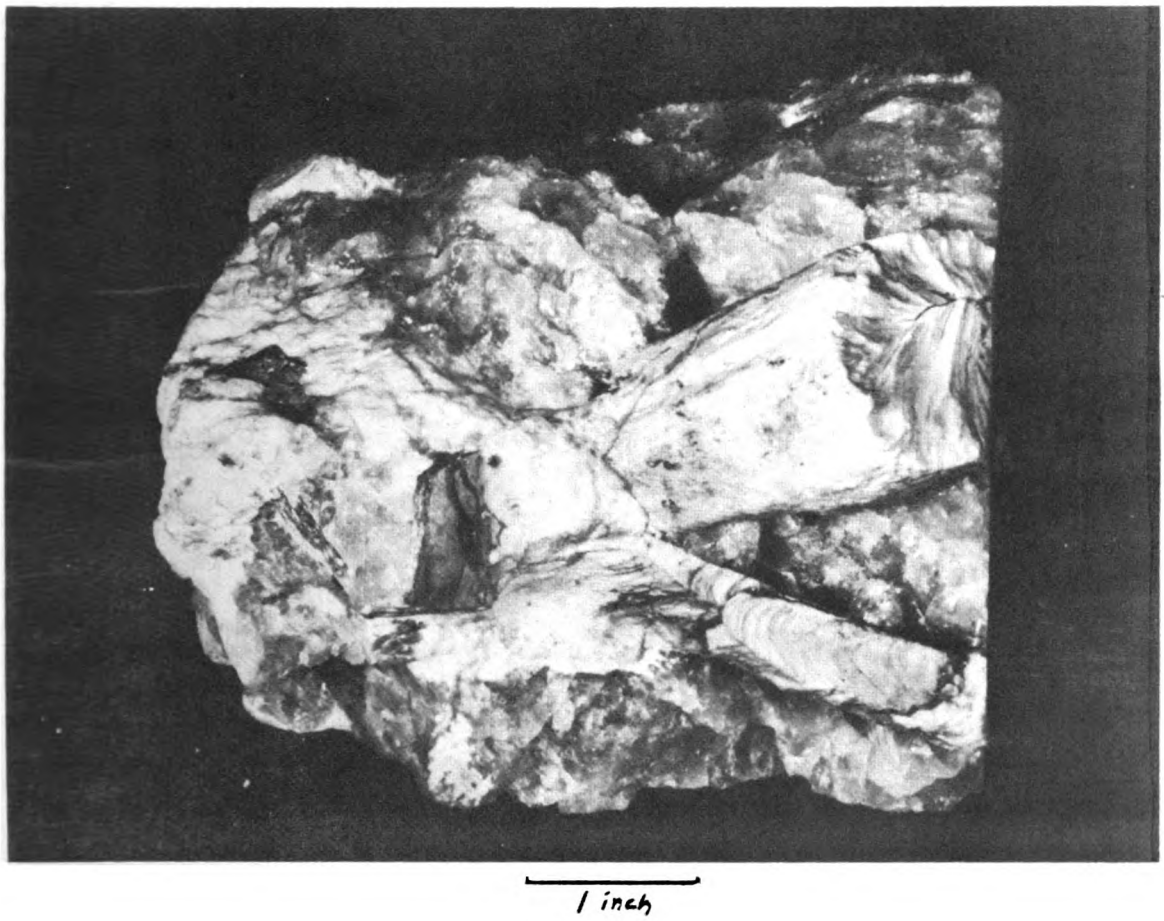

Figure 13.- Crystals of spodumene replaced by cymatolite, Isinglass Hill, 1/2 mile east of West Chesterfield, Mass.

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A little spodumene can still be found, and some good replacements by cymatolite of well-formed crystals buried in quartz are shown in figure 13. Some cymatolite enclosed fresh spodumene and some borders cracks, where it apparently replaces quartz and microcline. It was such material from this quarry that Julien[66] called "aglaite."

Spodumene has been reported on the Merryfield farm 2-1/2 miles north of West Chesterfield, and a little lepidolite, cookeite, and red, blue, and green tourmalines have been said to occur in Clark's Ledge, a pegmatite halfway between the farm and the village and 1/4 mile east of the road. The pegmatite is 20 feet wide, several hundred feet long, and stands 35 feet above the slope on the lower side and in places about as much on the upper side.

We found a few small, glassy beryls and a very little autunite, but no lithium minerals except green tourmalines.

Erving. - About 2 1/2 miles north of Erving (on Miller's River in Franklin County) and 100 yards east of Jacks Brook are angular chunks of a simple, white pegmatite that contains spodumene crystals 2 feet or more long, 2 inches wide, and thinner than wide. Besides the spodumene there are only quartz, some white feldspar, and a few garnets (spessartite). The spodumene is well-alined, as if formed in cracks, and some is light olive-green. No tourmaline was seen. Many other boulders were seen in a wall a quarter of a mile southeast, in which were some lustrous small beryls. The pegmatite is not known in place.

Pochaug Creek. - At a house known as the W. A. Brown house, just north of Pochaug Creek, on a side road on the northwest side of the Northfield-Winchester road, a piece of pegmatite 10 feet wide is exposed in the side of a barn for which it was cut through. It contains probably between 10 and 15 percent of spodumene and no dark minerals. Whether it is a large boulder or a small lens in place is uncertain, but it seems somewhat more probable that it is a lens.

Huntington. - Lithium-bearing pegmatites in the town of Huntington, formerly called Norwich, received considerable notice 75 years or more ago because of the unusual minerals found in them. They were first described by Hartwell and Hitchcock,[67] who described the deposits as in the north part of Norwich and as being large quartz veins "with albite and

66/ Julien, Alexis A., Aglaite, a New Mineral Species: Eng. and Min. Jour., vol. 23, 1877, p. 217.

67/ Hartwell, C., and Hitchcock, E., Jr., On a New Spodumene Locality at Norwich, Mass.: Am. Jour. Sci., 2d ser., vol. 10, 1850, pp. 264-265.

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feldspar" striking north through a hill of mica slate. The spodumene was mostly

> in one large vein, which appears at the surface only in two places about 30 rods apart. Associated with the spodumene are crystals of staurotide[68] of a new form, mica, imperfect specimens of beryl, and enormous black and blue tourmalines not perfect in figure.

Some crystals of spodumene were more than a foot long, but most of it was "massive" and in albite crystals extending into quartz. In one pegmatite the spodumene was "in a decomposed state, nearly as soft as gypsum." They state that "The spodumene is doubtless abundant, though a large quantity is not attainable without great expense." The mineral called staurotide was referred to as alluaudite[69] and triplite[70] by others but proved to be triphylite.[71] We have not seen the deposit.

Chester. - Ebenezer Emmons[72] described "granite veins" in Chester without taking the trouble to tell where to find them. The quartz in all was fetid, and one pegmatite was said to be

> four feet thick, and is twisted and contorted in a remarkable manner. It contains green and blue tourmaline, rose quartz, emerald, cleavelandite, and prismatic mica. One crystal of blue tourmaline is to be seen 3 inches in diameter. One of green has been detached measuring 2 inches and enclosing one of blue.

He did not recognize other lithium minerals and, of course did not know that the colored tourmalines contained lithium, but Dewey,[73] in the same

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68/ Staurolite.

69/ Craw, W. J., On the Analysis of Phosphate from Norwich, Massachusetts.: Am. Jour. Sci., 2d ser., vol. 11, 1851, p. 99.
Shepard, Charles H., On the triplite (alluaudite) of Norwich, Massachusetts.; Am. Assoc. Advance. Sci. Rept., 6 meeting, 1852, p. 234.

70/ Mallet, J. W., On the Phosphates of Iron and Manganese: Am. Jour., Sci., 2d ser., vol. 18, 1854, pp. 33-34.

71/ Brush, George J., On the Occurrence of Triphylene at Norwich in Massachusetts: Am. Jour. Sci., 2d ser., vol. 34, 1862, p. 402.

72/ Emmons, E. Notice of the Granitic Veins and Beds in Chester, Massachusetts.: Am. Jour. Sci., vol. 8, 1824, pp. 250-252.

73/ Dewey, Chester, Additional Remarks on the Geology of a Part of Massachusetts.: Am. Jour. Sci., vol. 8, 1824, p. 243.

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publication, mentions (also disregarding the exact locality) that spodumene occurs "in small quantity in granite, Chester, ***yellowish or pale green."

In 1878 Julien[74] said:

> In the town of Chester, about 1 mile north of Chester Village, the vein in the township of Chester was first discovered and opened by E. Emmons, and the spodumene was found to be associated with smoky quartz, muscovite, cleavelandite, indicolite, etc. In 1870, however, I could find no spodumene remaining in a small vein of this general character, showing traces of blasting, which seemed to be the one opened by Emmons.

We have not found the pegmatite.

Cape Ann. - Cryophyllite, a lithium-bearing mica that is dull emerald-green "in axial directions" and "brownish-red in the direction of the lateral axes," was described by Cooke[75] as a component of "granite ledges - forming the extremity of Cape Ann." The "granite ledges," like the "granite veins" or "granite dikes" of earlier writers, were pegmatites - a word that did not gain acceptance until later. His mean analysis was:[76]

Analysis of cryophyllite from Cape Ann, Mass.
(Josiah P. Cooke, analyst)

	Percent
Silica	51.49
Fluoride of silicon	3.42
Alumina	16.77
Sesquioxide of manganese	.34
Sesquioxide of iron	1.97
Protoxide of iron	7.98
Magnesia	.76
Potassa	13.15
Lithia	4.06
Soda	Trace
Rubidia	Trace
	99.94

74/ Julien, Alexis A., On Spodumene and Its alterations, From the Granite Veins of Hampshire County, Massachusetts.: Ann., New York Acad. vol. 1, 1877-80, pp. 319, 321.

75/ Cooke, Josiah P., On Cryophyllite, a New Mineral Species of the Mica Family, with Some Associated Minerals in the Granite of Rockport, Massachusetts.: Am. Jour. Sci., 2d ser., vol. 43, 1867, pp. 217-230.

76/ Cooke, J. P., Work cited in footnote 75, p. 220.

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W. J. Knowlton[77] reported a very small quantity of cesium in the cryophyllite.

Cooke also found 0.59 percent of lithia and traces of rubidia and soda in lepidomelane that occurred with the cryophyllite, and in much larger quantity.

Warren and McKinstry[78] give a list of more than 20 minerals found in the pegmatite, including the unusual minerals fayalite, cyrtolite, allanite, fergusonite, yttrocerite, tantalite, thorite, gadolinite, and danalite, but no tourmaline. The cryophyllite is rare, and the deposit has only mineralogic interest.

Connecticut

Branchville. - Brush and Dana[79] described a lithium-bearing pegmatite at Branchville thus:

> It [the spodumene] is, after the feldspars, mica and quartz, the most important of the original minerals of the locality, and occurs, though mostly in an altered condition, in very large quantities.
>
> The greater part of the unaltered spodumene occurs in confusedly crystalline masses. ***. It is possible to obtain the mineral nearly pure, though somewhat intermingled with albite, in blocks weighing several hundred pounds. The associated minerals in addition to the albite and a little quartz and mica are apatite, lithiophilite, columbite, garnet, and uraninite, with various other uranium minerals formed from alteration.
>
> In addition to this massive variety, the spodumene also occurs in an unaltered condition as nuclei of distinct pseudomorphous crystals. These crystals often occur of enormous size, imbedded for the most part in massive quartz, though sometimes extending into the albite. ***. One of

77/ Knowlton, W. J., On a New Mineral from Rockport, Massachusetts.: Am. Jour. Sci., 2d ser. vol. 44, 1867, p. 226.

78/ Warren, Charles H., and McKinstry, Hugh E., The Granite and Pegmatites of Cape Ann, Massachusetts.: Proc. Am. Assoc. Advance. Sci., vol. 59, 1924, pp. 315-357.

79/ Brush, George J., and Dana, Edward S., On the Mineral Locality at Branchville, Conn., (4th paper): Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 257-258.

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the finest crystals we have found thus far had, as imbedded in the quartz, a length of 3 feet, a width of 8 inches, and a thickness of 2 inches.

The spodumene was a fine amethystine color where unaltered. Of course, the term "enormous" was used before the really large crystals of spodumene of the Black Hills, S. Dak., reaching 42 feet in length, 6 feet in width, and 3 feet in thickness, had been found. The spodumene is largely altered to cymatolite, which the authors state is a mixture of muscovite and albite. The deposit has had no economic value as a source of lithium.

Cobalt. - The Paul Anderson farm on the east side of the Hurd Park Road a mile south of Hurd Park and 5 miles south of the village of Cobalt is on the side of a ridge several hundred feet high. At the top of the ridge a metamorphic pegmatite 50 or 60 feet wide and 300 feet long follows the strike of the ridge and the gray mica schist, about north and at the south end stands 15 or 20 feet above the general contour.

Some quarrying was done near the north end of the pegmatite a good many years ago. At this point the pegmatite is largely quartz in which are buried mixed masses of a beautiful purple lepidolite and cleavelandite, some of which follow distinct cracks in the quartz and are 10 to 12 inches in diameter. Much of the lepidolite is in globular radial aggregates ranging from less than 1/4 inch to 3/4 inch in diameter. Possibly 4 or 5 tons of lepidolite, more or less mixed with cleavelandite and quartz, have been thrown in a pile. All came from an excavation about 20 feet long, 6 to 10 feet wide, and 4 to 6 feet deep.

A visual estimate from the spectrographic pattern of the lepidolite gave K_2O, 5.0; Na_2O, 1.0; Li_2O, 5.0; Rb_2O, 3.0; Cs_2O, 1.0; and for a piece of microcline the estimate was K_2O, 5-10.0; Na_2O, 5.0; Li_2O, not determinable; Rb_2O, 2.0; Cs_2O, 0.1.

Some green and blue-black tourmalines are distributed through the pegmatite, and a little triplite edged round by lepidolite and blue tourmaline was found. From surface indications alone, this appears to be next to Black Mountain, Maine, the largest lepidolite deposit seen in New England; but even so, remembering the erratic nature of pegmatitic deposits, no prediction as to further quantities can be made.

Considerable work has been done for mica between the lepidolite-bearing portion and the east wall of the pegmatite. An excavation 30 by 50 feet and more than 20 feet deep (the bottom was covered with water

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when visited in April, 1942) has been dug, but only one small chunk of lepidolite could be seen in the walls and none was found in the dump.

A number of large pegmatites outcrop to the north and east on the top of the ridge, but no lithium minerals were seen in them.

Portland. - The Strickland feldspar quarry, long famous for its pegmatitic minerals, is on Collins Hill, town of Portland, and is about 8 miles by road N. 30° E. from Middletown.

It is on a pegmatite 20 to 25 feet thick, following the schistosity, and dips about 60° SE. It was not being worked at the time of our visit, and the opening was filled with water within 50 to 60 feet of the top. The workings had gotten underground and are perhaps 300 feet long. Southwest across a road, underground work for mica was continuing through a shaft, which when visited in August 1940 was said to be 190 feet deep.

The dumps are very large, and the material is about the same in each. In them are fine-grained pieces of lepidolite and some spodumene partly changed to cymatolite. Some is in rough-surfaced but attractive crystals. One crystal more or less representative was 8 inches long 1-1/8 inches thick, and 2 inches broad was twinned with a somewhat smaller crystal. The cleaved crystal was china-white in the lower part and rosy near the tip. Although all New England spodumenes tried by us show a reddish luminescence, mostly more or less dull, the crystals from the Strickland pegmatite show a brighter, more pleasing, orange-pink luminescence under ultra-violet rays of 3,500Å to 7,000Å.

The total of the lithium minerals is almost inconsequential, although 2 or 3 tons of lepidolite has been sold to dealers in specimens.

Dr. David Keppel courteously sent us specimens of feldspar from the Strickland dump, and M. Allen Northup sent a small specimen of transparent beryl and another of opaque pink beryl, on which visual estimates from spectroscopic plates were made, as follows:

	K_2O	Na_2O	Li_2O	Rb_2O	Cs_2O	In_2O	Ge_2O	Ga_2O_3
A-1 white microcline	5.0	3.0	n.d.	1.0	n.d.	n.d.	n.d.	0.1
B-1 buff microcline	5.0	3.0	n.d.	1.0	0.1	n.d.	n.d.	.1
C-1 spongy microcline	1.0	5.0	n.d.	.2	n.d.	n.d.	n.d.	.5
Transparent beryl	.5	3.0	3.0	.1	.5	-	-	-
Opaque pink beryl	.5	1-5.0	1-5.0	.5	.5	-	-	-

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Other deposits. - Small quantities of lepidolite and other lithium minerals are found in pegmatites in White Rocks, a hill on the south side of the Connecticut River 3 miles southeast of Middletown; the Gillette quarry in Haddam; and in other pegmatites in the neighborhood.

Schairer[80] notes:

"Cookeite in Portland, Haddam Neck, and White Rocks." It has no economic importance.

New Hampshire

Occurrences. - Lithium minerals have been found in a number of pegmatites of New Hampshire, but none have so far proved to be in quantities of commercial value, although most of the Maine occurrences are close to the New Hampshire line. Meyer's[81] compilation of mineral localities has been drawn on for part of the occurrences.

Amblygonite has been found in small quantity at Center Strafford, and questionably in Alstead. Lepidolite, a few flakes only, is reported by Bannerman[82] in the Ruggles pegmatite, Grafton; it is also found in small quantity in the Turner quarry in Marlow and in the Chickering quarry, Walpole. Lithiophilite is also reported by Bannerman[83] as in small quantity in the Ruggles pegmatite. Zinnwaldite has been found in the Palermo pegmatite, Groton. Spodumene has been found in the Chickering quarry, Walpole (not now operated), but all that was seen by us was badly altered to a substance that may be a reddish pinite (not yet studied); in Winchester; and in Alstead, where the mineral is white, pink, or light green. Triphylite has been found in the Sargent mica workings in Claremont; in the Palermo pegmatite, Groton; Chickering quarry, Walpole; and Ruggles pegmatite, Grafton; and a mass 10 feet through was found at Center Strafford.

80/ Schairer, John F., The Minerals of Connecticut: Connecticut State Geol. and Nat. Hist. Survey Bull. 51, 1931, pp. 43, etc.
81/ Meyers, T. R., New Hampshire Minerals and Mines: Report to the New Hampshire Planning and Development Commission, 1941, 49 pp.
82/ Meyers, T. R., Work cited in footnote 80, p. 26.
83/ Meyers, T. R., Work cited in footnote 81. p. 24.

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Walter Hammond courteously supplied specimens of microcline from a number of New Hampshire pegmatites on which the results of visual estimates from spectrographic lines are given below (only 32A was collected by us):

		K_2O	Na_2O	Li_2O	Rb_2O	Cs_2O
26.	Bala quarry, Beryl Mountain, Acworth	7.0	5.0	n.d.	1.0	n.d.
27.	Colony quarry, Acworth	3.0	2.0	n.d.	.5	n.d.
28.	Porter quarry, Acworth	5.0	3.0	n.d.	.5	n.d.
29.	Creamy, Keene mine, Alstead	5.0	3.0	n.d.	.5	n.d.
30.	Brownish, Keene mine, Alstead	5.0	5.0	n.d.	.5	n.d.
31.	Turner quarry, Alstead	5.0	3.0	n.d.	.5	0.2
32.	Ruggles quarry, Grafton Center, commercial feldspar	5.0	5.0	n.d.	.5	n.d.
32A.	Ruggles quarry, Grafton Center, perthite with potash fraction in part of specimen replaced by quartz and muscovite	5.0	5.0	n.d.	.5	n.d.
33.	Chickering quarry, Walpole	5-10.0	5.0	0.2	2.0	.5
34.	Damasiak quarry, Walpole	7.0	5.0	n.d.	1.0	n.d.

The almost total lack of cesium and lithium and the small quantity of rubidium is striking. The specimen from the Chickering quarry is a notable exception. It is likewise remarkable that no gallim could be found in any of the specimens examined. Indium and germanium also were missing.

Vermont

Mechanicsville. - The only occurrence of the rare alkalis known in Vermont is in a phlogopite found 3-3/4 miles southeast of Mechanicsville, which is 25 miles southeast of Rutland.

A specimen of the phlogopite furnished by Harold Ladd Smith was shown by spectrochemical tests to contain about 1 percent of rubidia. In a later and larger specimen the phlogopite formed a small percentage of a green mass of actinolite and less calcite. It appears to be from a metamorphosed limestone, though nothing is known of field relationships. A specimen of the phlogopite was picked from the mass, a second specimen of the ground mass of actinolite and calcite was taken, and a third specimen, which was like the second, was treated with dilute hydrochloric acid to remove the calcite and any other soluble minerals. Visual estimates of the alkalis were made spectrochemically, with the following results:

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	K_2O	Na_2O	Li_2O	Rb_2O	Cs_2O	Ga_2O_3
43. Phlogopite	5.0	0.3	1.0	0.5	n.d.	0.1
44. Actinolite and calcite	1.0	1.0	n.d.	n.d.	n.d.	.1
45. Actinolite treated with HCl	1.0	1.0	n.d.	.5	n.d.	.1

The specimens contained no indium or germanium. Nothing is known of the quantity of phlogopite available, and although the occurrence is interesting mineralogically and geologically it promises little economically.

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